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144425

FINAL REPORT

For The

THERMAL CONTROL EXTRAVEHICULAR LIFE SUPPORT SYSTEM

August 1975

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Abstract

This report summarizes the results of a comprehensive study which defined an Extravehicular Life Support System Thermal Control System (TCS), presents the design of the prototype hardware and provides a detail summary of the prototype TCS fabrication and test effort.

Thirteen Heat Rejection Subsystems, thirteen Water Management Subsystems, nine Humidity Control Subsystems, three pressure control schemes and five temperature control schemes are evaluated. Sixteen integrated TCS systems are studied, and an optimum system selected based on quantitative weighing of weight, volume, cost, complexity and other factors. The selected subsystem contains a sublimator for heat rejection, bubble expansion tank for water management, a slurper and rotary separator for humidity control, and a pump, a temperature control valve, a gas separator and a vehicle umbilical connector for water transport. The prototype hardware complied with program objectives.

Foreword

This is the final report for the Thermal Control System Program. This effort was conducted by Hamilton Standard under NASA contract NAS 9-13574 for the Lyndon B. Johnson Space Center of the National Aeronautics and Space Administration from June 1973 to August 1975.

Special thanks are due to the Contract Technical Monitor, Mr. Michael Rouen, Crew Systems Division of the NASA Lyndon B. Johnson Space Center, for his advice and guidance.

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HRS	Heat Rejection Subsystem
WMS	Water Management Subsystem
HCS	Humidity Control Subsystem
WTS	Water Transport Subsystem
LCG	Liquid Cooling Garment
EVLSS	Extravehicular Life Support System
TCS	Thermal Control System
EVA	Extravehicular Activity
PLSS	Apollo Portable Life Support System
ALSA	Skylab Astronaut Life Support Assembly

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1.0 SUMMARY

Hamilton Standard has developed a Thermal Control System (TCS) for an advanced zero gravity Extravehicular Life Support System (EVLSS). This development effort was conducted under Contract NAS 9-13574 to NASA's Johnson Space Center. The scope of the program included the selection, design, fabrication and test of a zero gravity TCS that meets its objectives of long life, low cost, and minimum maintenance.

The TCS consists of a Heat Rejection Subsystem (HRS), a Water Management Subsystem (WMS), a Humidity Control Subsystem (HCS), and a Water Transport Subsystem (WTS).

The basic requirements and operating conditions for the TCS are as follows:

- It must be capable of zero "g" recharge with vehicle supplied water saturated with nitrogen at 248 KPa (36 psia).
- It must be capable of non-venting umbilical operation for up to 4.5 hours.
- It must be operable and capable of rejecting the maximum thermal load within ten minutes of start up (design goal is five minutes).
- There must be no free water spillage when starting up.
- The TCS must be non-venting within five minutes of shutting off feed water.
- The TCS shall have a useful life of 100 mission cycles or 15 years.
- The TCS shall separate and use or store up to .77 Kg (1.7 lbs) of condensate water.
- The total heat load shall be 8.261×10^3 kilo joules (7,824 Btu) (four hours at 293 watts (1,000 Btu/hr) ave. met. load).
- The suit vent loop pressure will be 26.5 $\pm$ 1 KPa (3.85 $\pm$ .15 psi).
- The liquid loop pressure will be 24 to 158 KPa (3.5 to 22.85 psia).
- The vehicle water supply pressure will be 228 to 248 KPa (33 to 36 psia).

1.0 (Continued)

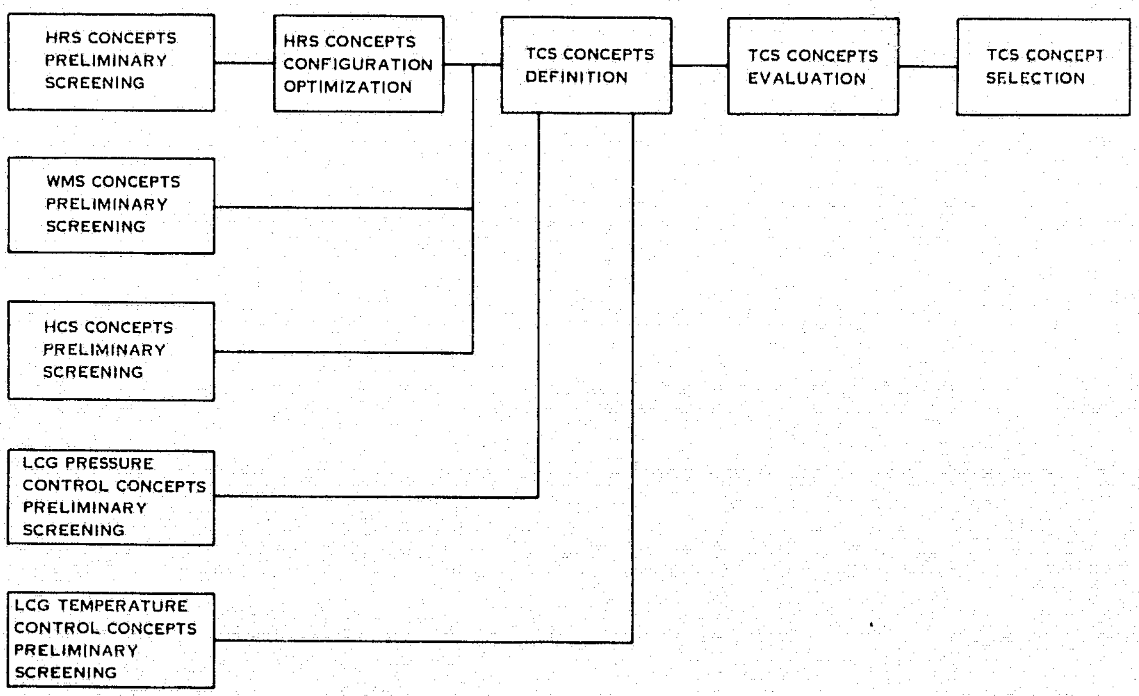
This is the Final Report for the Thermal Control Program.

The EVLSS TCS program consisted of two phases: 1) concept definition, evaluation, selection, and design of the selected system, and 2) concept fabrication and test.

The study consisted of definition of numerous candidate subsystem concepts, selection of competitive subsystem concepts based on an in-depth screening evaluation, combination of the competitive subsystems into system concepts, and selection of a system concept. Detail drawings of the selected concept were then prepared for fabrication of a feasibility TCS.

The approach used for each segment of the study consisted of the following steps:

1) Identification of the Evaluation Criteria
2) Identification of the Candidate Concepts
3) Screening of the Concepts
4) Selection of the Optimum Concept(s)



TCS Concept Selection Study Logic

Figure 1-1

1.0 (Continued)

The HRS was evaluated in two steps to first, identify the viable concepts, and then to optimize the configuration of these concepts. In the first step of the HRS selection, thirteen candidates were defined and were screened on the basis of safety, performance, development/availability and maintenance. Three promising candidates remained after this evaluation. In the second step of the HRS evaluation, ten configurations for these three concepts were defined and were assessed for life, hardware cost, EVLSS weight and EVLSS volume. This evaluation resulted in the selection of two HRS candidates.

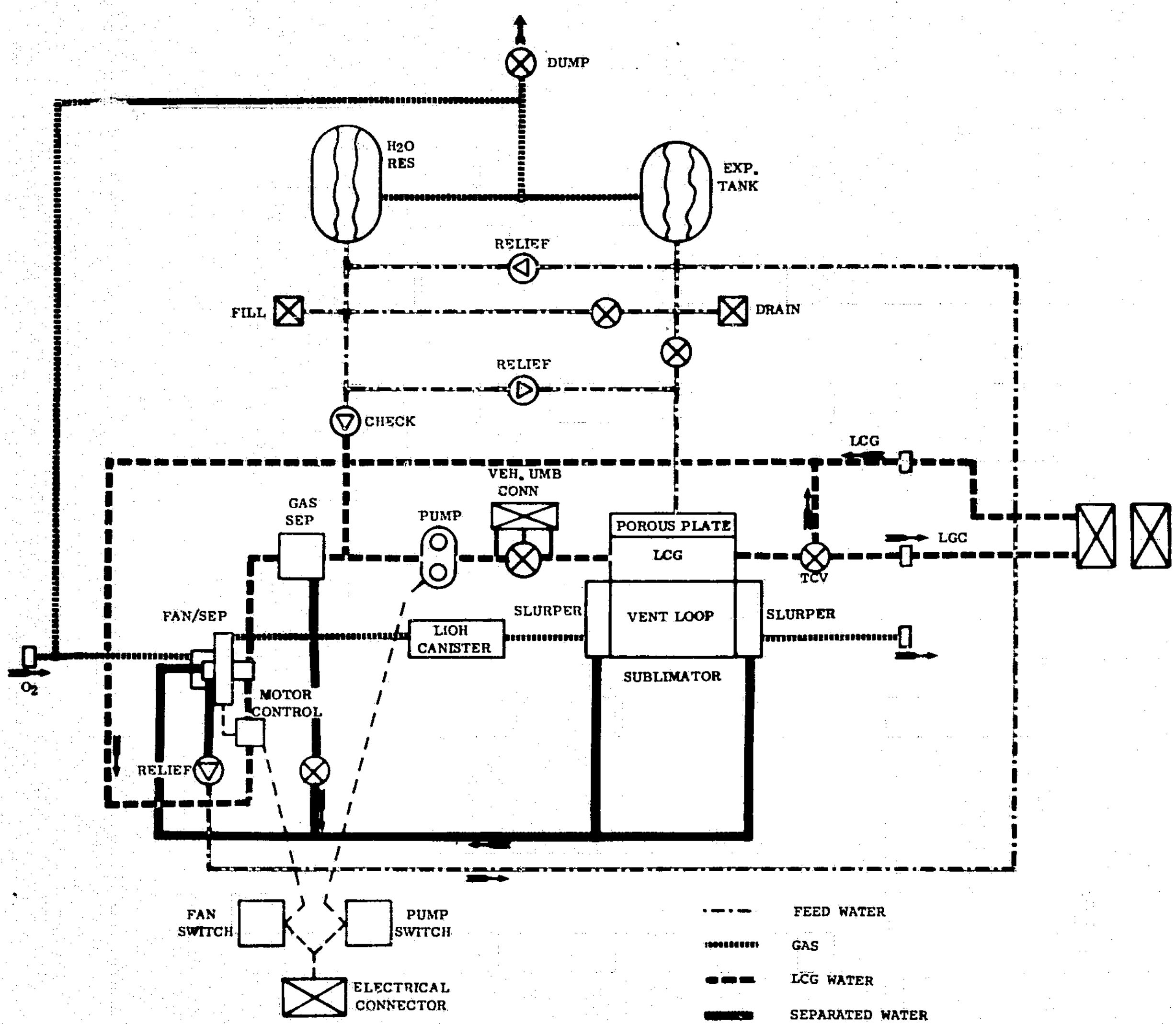
The WMS evaluation consisted of definition of thirteen candidates which were screened on the basis of safety, performance, development/availability, gross vehicle launch weight and EVLSS volume. This evaluation resulted in selection of three WMS candidates for further study.

For the HCS selection, nine candidates were defined and were screened on the basis of safety, performance, development/availability, gross vehicle launch weight and EVLSS volume. Seven candidates were selected for further study.

For the LCG pressure control, three concepts were defined, and two selected after evaluation against safety, performance, development/availability, EVLSS volume and EVLSS weight. In the definition of TCS concepts, the method of pressure control was selected on the basis of compatibility with the systems defined by the HRS, WMS, and HCS.

Evaluation of the LCG temperature control consisted of evaluating five candidates against safety, performance, development/availability and EVLSS volume. A single concept was selected for use in the TCS.

The two competitive Heat Rejection Subsystems, three competitive Water Management Subsystems, and seven competitive Humidity Control Subsystems were combined to form sixteen candidate Thermal Control Systems. These systems were evaluated on the basis of performance, vehicle launch weight, EVLSS volume, program cost, operability, complexity, and reliability. The selected concept, shown in Figure 1-2, was the least weight, least volume, least cost, least complex, most operable, and most reliable of the sixteen concepts evaluated.



TCS SCHEMATIC

FIGURE 1-2

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1.0 (Continued)

The selected system consists of a bubble expansion tank water management subsystem, a three-fluid sublimator heat rejection subsystem, and a first stage slurper/second stage motor rotary separator humidity control subsystem. The pump, Temperature Control Valve (TCV), gas separator, and vehicle umbilical connector are the component parts of the Water Transport Subsystem. During normal operation (venting mode), water enters from the LCG and is circulated by the pump through the vehicle umbilical connector shutoff valve, the sublimator, and the temperature control valve and back to the LCG. The LCG water is cooled via conduction to the porous plate of the sublimator. The vent loop flow coming from the suit passes through the LiOH canister and is circulated by the fan through the vent loop portion of the sublimator/slurper and is returned to the suit. Cooling is provided by conduction to the LCG circuit.

During operation in the non-venting mode (liquid cooling provided by umbilical to a vehicle heat exchanger), a vehicle liquid umbilical is connected to the system, and the umbilical connector shutoff valve is closed routing all the LCG water through the vehicle heat exchanger.

Coolant thermal control is achieved using the temperature control valve which varies the water flow to the LCG. LCG pressurization and makeup is supplied by the feed water circuit via a check valve between the two circuits.

Water separation is accomplished in two stages. Approximately three percent of the main stream flow is diverted through the slurper to the upstream side of the fan. The pressure differential between these two points continually drains the condensed water from the heat exchanger. The water/gas mixture enters the rotary separator which separates the water from the gas stream. The separated water is delivered to the feed water circuit through a relief valve which prevents the introduction of gas to the feed water circuit.

The expansion tank serves two functions. During operation in the non-venting mode when no feed water is being used, it stores the condensate separated from the vent loop and for operation in the venting mode; it accepts the gas released when the pressure in the main reservoir drops from 248 KPa (36 psia) to 27 KPa (4 psia).

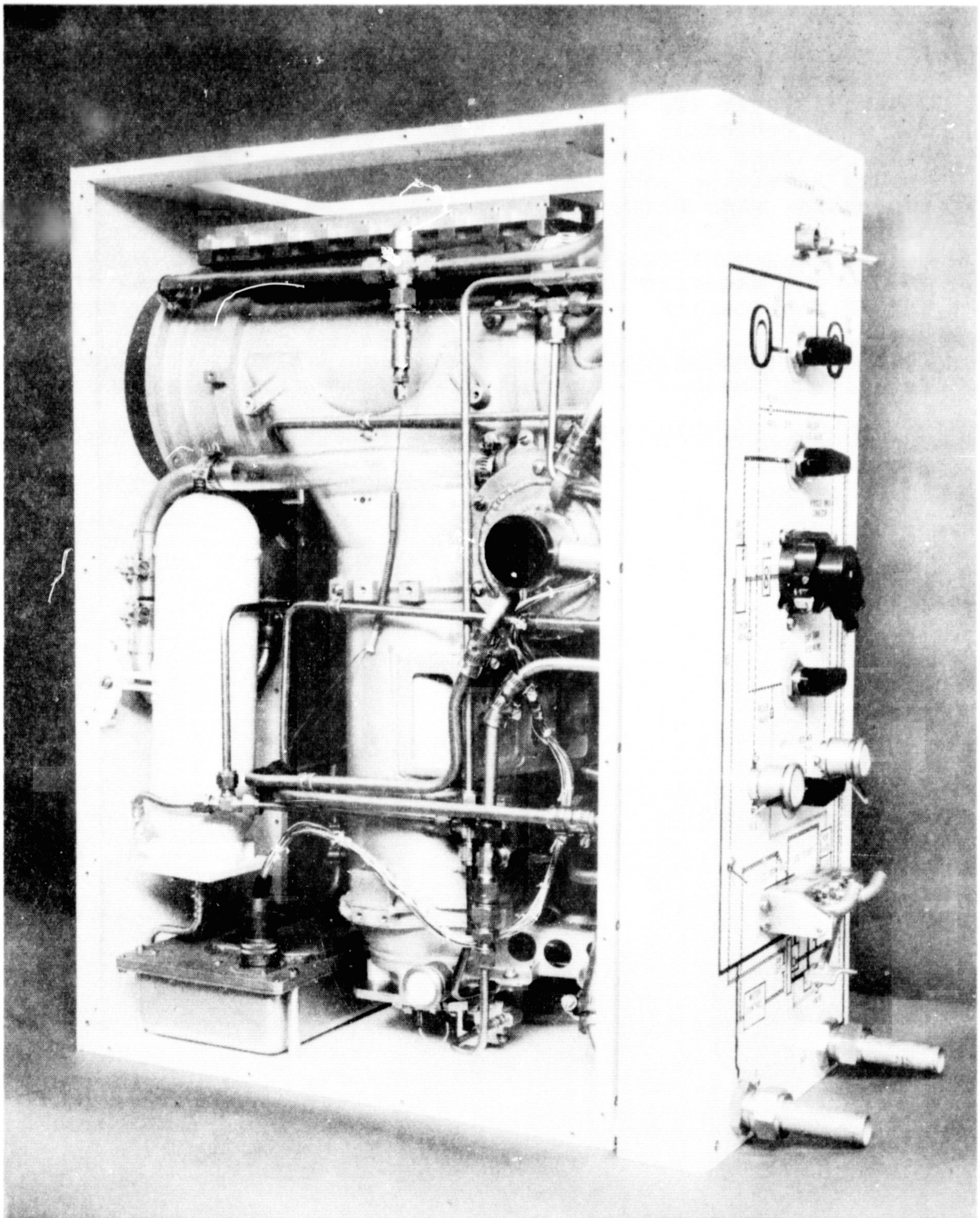
Detail designs were prepared for each subsystem completing the Phase I activity.

1.0 (Continued)

During Phase II, each subsystem was fabricated and subjected to a comprehensive development test program which demonstrated that each complied with the Work Statement requirements.

Subsequent to the subsystem testing, the HRS, WMS, and HCS were combined to form the TCS which was subjected to a series of system level development tests. The TCS tested complied with all applicable Work Statement requirements. After completion of the test program, the TCS was updated to include the Water Transport Subsystem components, and the completed system shown in Figure 1-3 was delivered to NASA.

This system complies with all requirements, uses logical extension of proven Apollo technology, and was found to be best in all areas after an extensive study of existing and evolving technology.



THERMAL CONTROL SYSTEM

FIGURE 1-3

2.0 INTRODUCTION

In June of 1973, Hamilton Standard was awarded a contract to develop an Extravehicular Life Support System (EVLSS) Thermal Control System (TCS) which is operable in a zero "g" environment for extravehicular activity (EVA) and meets the criteria of low cost, minimum maintenance, minimum in-flight servicing, minimum ground servicing and long life. This contract was completed in two phases with Phase I consisting of the study, selection, and design of a TCS consisting of Heat Rejection Subsystem (HRS), Water Management Subsystem (WMS), Humidity Control Subsystem (HCS), and Water Transport Subsystem (WTS), and Phase II consisting of fabrication and testing of each subsystem and the total TCS.

This Final Report summarizes the Phase I effort and describes in detail the Phase II effort.

3.0 OBJECTIVES

The objectives of this two phase program were:

a. Establish by detail evaluation the best EVLSS Thermal Control System (TCS) which is operable in zero "g" and which meets the objectives of long life, minimum maintenance, and low cost.

b. Prepare detail drawings suitable for fabrication of a feasibility TCS.

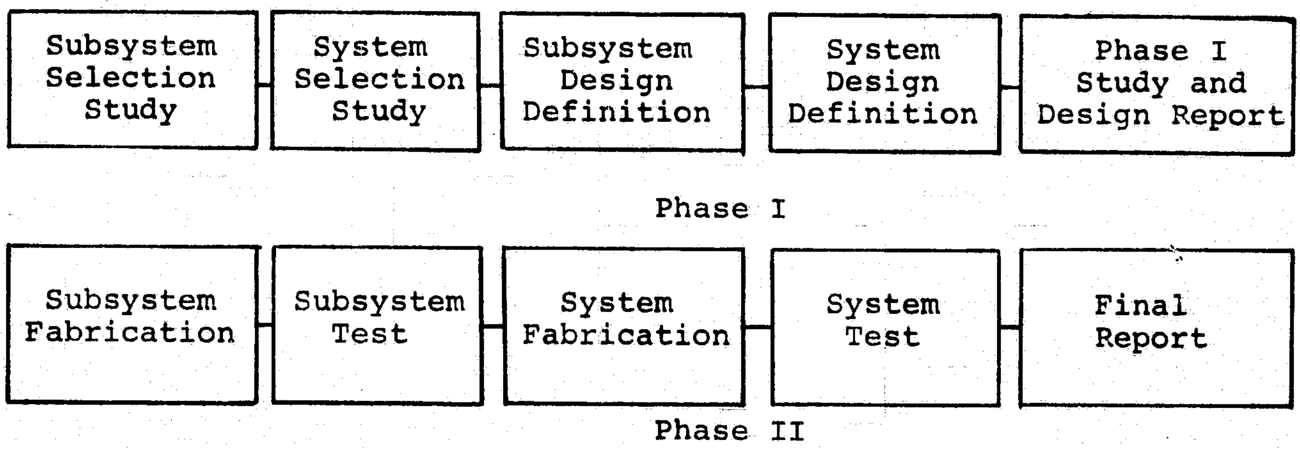
c. Fabricate the TCS hardware.

d. Conduct subsystem and system development tests to verify compliance with Work Statement requirements.

4.0 DISCUSSION

4.1 Background and Requirements

The Thermal Control System (TCS) program was conducted in two phases as shown in Figure 4-1-1. A detailed presentation of the Phase I activity is contained in Hamilton Standard Phase I report, HSPC-75.T05. The Final report briefly summarizes the Phase I effort and provides a comprehensive description of the Phase II effort.



Thermal Control System Program Logic
Figure 4-1-1

This report section is divided into the following subsections representing the major elements of the program work breakdown structure:

- Subsystem and System Concepts Study
- Concepts Design
- Subsystem Fabrication and Test
- System Fabrication and Test

The Thermal Control System (TCS) consists of a Heat Rejection Subsystem (HRS), a Water Management Subsystem (WMS), a Humidity Control Subsystem (HCS), and a Water Transport Subsystem (WTS). The HRS is used to reject heat generated by a crewman and equipment during EVA; the WMS is used to store and deliver expendable water to the HRS; the HCS is used to separate, store and/or process the condensate generated during an EVA, and the WTS is used to circulate cooling water to the LCG and EVLSS components requiring active cooling.

4.1 (Continued)

The detail requirements for the TCS are defined in a mini specification which is included in Appendix A. Table 4-1-1 is a synopsis of the TCS requirements and operating conditions.

4.2 Subsystem and System Concepts Study

This section of this report is a brief summary of the concept selection effort conducted during Phase I. A comprehensive summary of the selection effort is included in the Phase I Engineering and Technical Data Report, HSPC-75.T05.

4.2.1 Study Logic

The Thermal Control System was divided into five subareas for investigation.

- Heat Rejection Subsystem (HRS)
- Water Management Subsystem (WMS)
- Humidity Control Subsystem (HCS)
- LCG Pressure Control (included in WMS)
- LCG Temperature Control (included in WTS)

The approach used in the investigation of each subarea consisted of:

- Definition of Evaluation Criteria
- Definition of Candidate Concepts
- Evaluation of the Concepts
- Selection of the Optimum Concept(s)

Once the evaluation of the subarea level was completed, the subarea concepts that had not been eliminated were combined to form candidate TCS concepts. Final evaluation of concepts was conducted at the system (TCS) level. The HRS, WMS and HCS were the driving factors in defining the TCS concepts, with compatible LCG pressure and temperature control concepts being selected for each system concept. The WTS components evaluated, other than the temperature control concept, were the same for all TCS concepts.

This study logic proceeded as shown in Figure 4-2-1, which shows how the steps used in selecting the final TCS concept were integrated.

4.2.2 Heat Rejection Subsystem

The Heat Rejection Subsystem (HRS) is a device which rejects the waste heat generated by a crewman and equipment during EVA. The HRS was evaluated in two steps. First, the basic functional

TABLE 4-1-1

TCS REQUIREMENTS AND OPERATING CONDITIONS

- It must be capable of zero "g" recharge with vehicle supplied water saturated with nitrogen at 248 KPa (36 psia).
- It must be capable of non-venting umbilical operation for up to 4.5 hours.
- It must be operable and capable of rejecting the maximum thermal load within ten minutes of start up (design goal is five minutes).
- There must be no free water spillage when starting up.
- The TCS must be non-venting within five minutes of shutting off feed water.
- The TCS shall have a useful life of 100 mission cycles or 15 years.
- The TCS shall separate and use or store up to .77 Kg (1.7 lbs) of condensate water.
- The total heat load shall be 8,261 x 10^3 kilo joules (7,824 Btu) (four hours at 293 watts (1,000 Btu/hr ave. met. load).
- The suit vent loop pressure will be 26.5 $\pm$ 1 KPa (3.85 $\pm$ .15 psi).
- The liquid loop pressure will be 24 to 158 KPa (3.5 to 22.85 psia).
- The vehicle water supply pressure will be 228 to 248 KPa (33 to 36 psia).

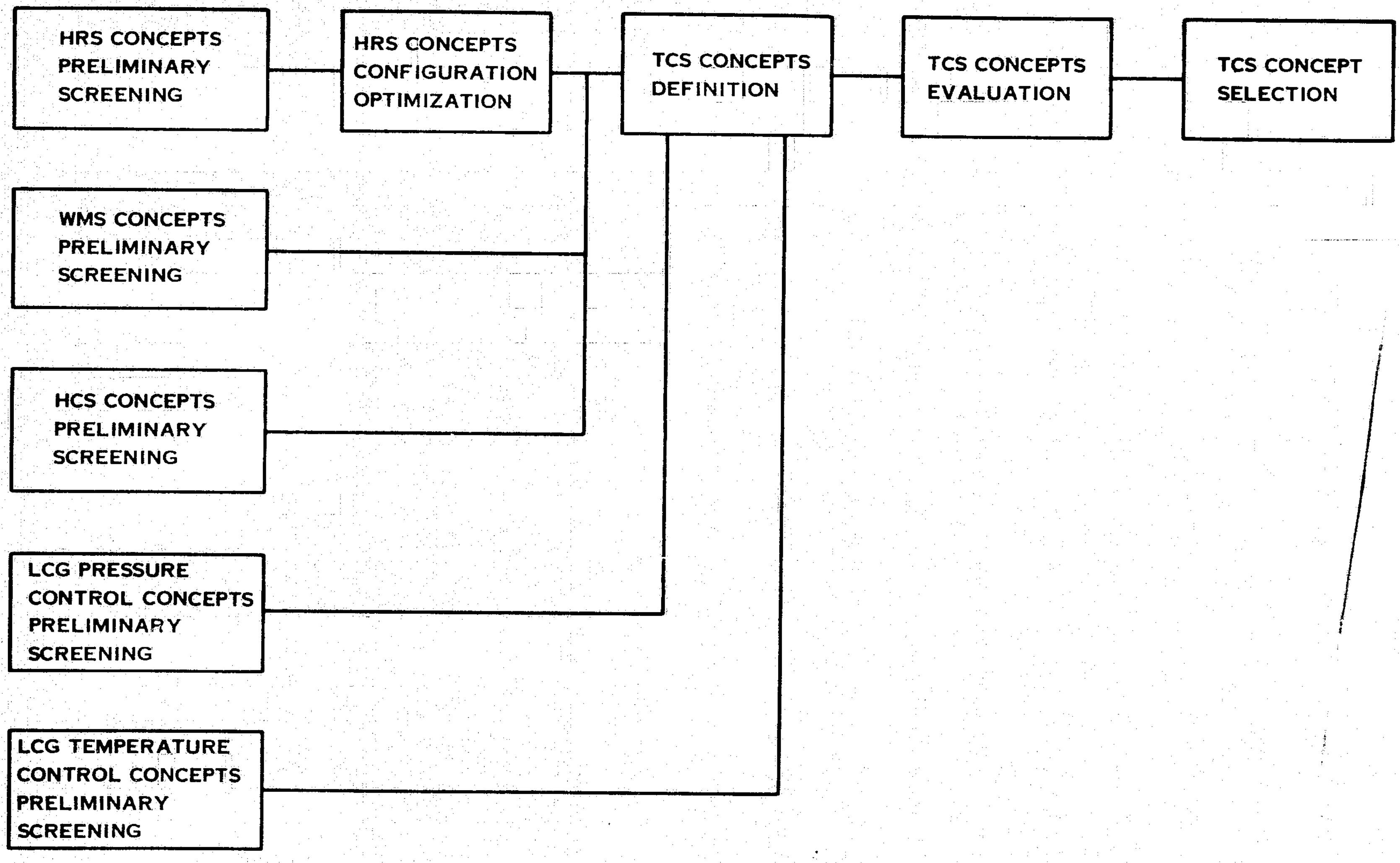


FIGURE 4-2-1
SUBSYSTEM AND SYSTEMS CONCEPT STUDY LOGIC

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4.2.2 (Continued)

concepts were screened to identify those viable for EVA conditions. Secondly, the viable concepts were configured into subsystem schematics to identify the optimum configuration for each.

Four water boilers, six flash evaporators, and three sublimator concepts were defined and evaluated. All the water boilers were eliminated from further consideration due to inherent performance and maintenance problems. Four of the flash evaporators were eliminated due to inability to meet performance requirements and high technology risk; two of the sublimators were eliminated due to inability to meet performance. The remaining candidates included a spraying flash evaporator with either a hydraulic or pneumatic nozzle and the replaceable plate sublimator.

For each of these Heat Rejection Subsystems, the following three heat exchanger schematic arrangements were considered.

Three-Fluid Heat Exchanger - This concept, shown in Figure 4-2-2, uses a common sink to cool two separate coolant passages. The vent loop is cooled by conduction to the LCG passage which is in turn cooled by conduction to the sink. The heat exchanger could use an optional second sink to provide direct cooling for both coolant passages.

Two Two-Fluid Heat Exchangers - This concept, shown in Figure 4-2-3, uses a sink to directly cool the LCG in the first two-fluid heat exchanger, and then the LCG loop cools the vent loop via a second two-fluid heat exchanger.

Two Independent Two-Fluid Heat Exchangers - This concept, shown in Figure 4-2-4, uses two sinks which are independently controlled. One sink cools the vent loop; the other sink cools the LCG. This combination, although employing two independent sinks, may be packaged into a single heat exchanger, but the LCG and vent loops are not thermally interconnected. This is the schematic arrangement used in the Apollo backpack sublimator. With this arrangement, cooling of the vent loop by a vehicle umbilical during a no vent mode of operation is not possible; thus, this concept was rejected.

The two viable heat exchanger arrangements were combined with the three HRS candidates for final subsystem evaluation. This evaluation considered the following elements:

1) The better flash evaporator nozzle,
2) The optimum flash evaporator shape,
3) The optimum flash evaporator heat exchanger arrangement,
4) The optimum sublimator configuration.

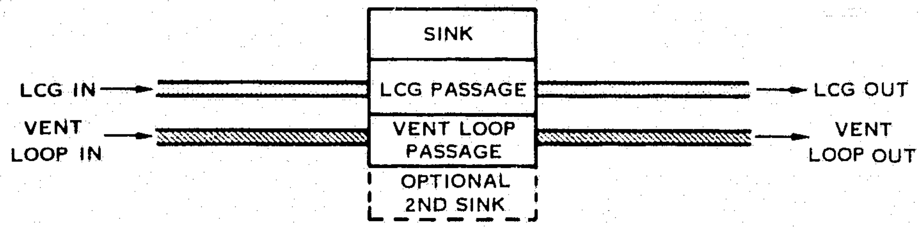

FIGURE 4–2–2
THREE–FLUID HEAT EXCHANGER

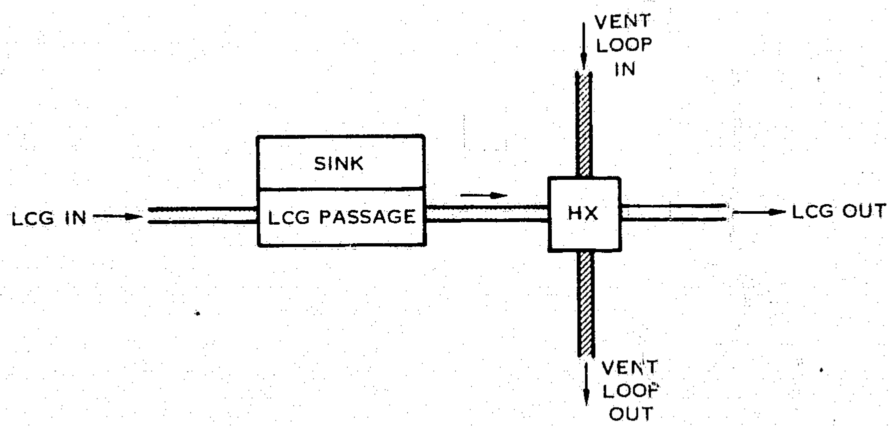

FIGURE 4–2–3
TWO TWO–FLUID HEAT EXCHANGERS

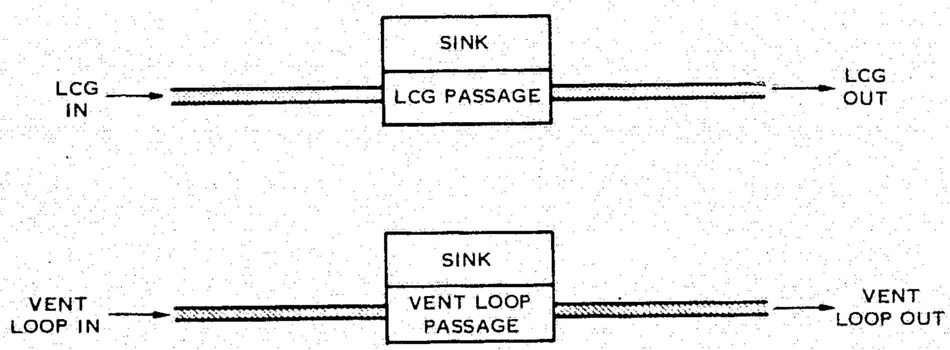

FIGURE 4–2–4
TWO INDEPENDENT TWO –FLUID HEAT EXCHANGER

4.2.2 (Continued)

The pneumatic nozzle flash evaporator was found to be noncompetitive from a weight, volume, and cost standpoint. A cylinder was found to be the most competitive shape for the flash evaporator. A two two-fluid heat exchanger was found to be best for the flash evaporator, while a three-fluid heat exchanger was found to be the most competitive configuration for the sublimator. These two HRS concepts were carried into TCS level evaluations, described in detail in the following paragraphs.

The spraying flash evaporator, with two-fluid heat exchanger, is shown in Figure 4-2-5.

The expendable water is sprayed through a hydraulic nozzle which breaks the liquid stream into droplets forming a hollow cone spray.

These droplets impinge on an aluminum cylindrical heat exchanger surface which is finned at the water droplet impact zone to provide more area for heat transfer. The chamber in which the evaporation takes place is vented to vacuum ambient. This maintains the chamber pressure to a level that promotes droplet evaporation. The water vapor released by the evaporation process exits the chamber through the vent hole.

The LCG flow circulates through passages in the evaporator wall. The heat transfer is accomplished by conduction from the LCG flow through the aluminum wall to the finned droplet impact zone to the vaporizing expendable water. The LCG outlet water temperature is monitored, and the feed water flow through the nozzle is controlled electrically to maintain a constant outlet temperature.

After exiting the flash evaporator, the cooled LCG flow passes to a stainless steel heat exchanger which is shown in Figure 4-2-6. It is utilized as a heat sink to cool the oxygen loop. This stainless steel cross flow unit is a plate-fin design with three oxygen loop passages. Four LCG loop passages make a single pass through the heat exchanger.

The three-fluid sublimator is shown in Figure 4-2-7.

The oxygen loop is cooled by making a single pass in the cross flow direction in a finned passage mounted adjacent to the LCG finned passage. The LCG loop is in turn cooled by feed water sublimation through the porous plate. The rate at which the feed water sublimates is proportional to the heat load imposed by the vent and LCG loops; thus, this device is self-controlling.

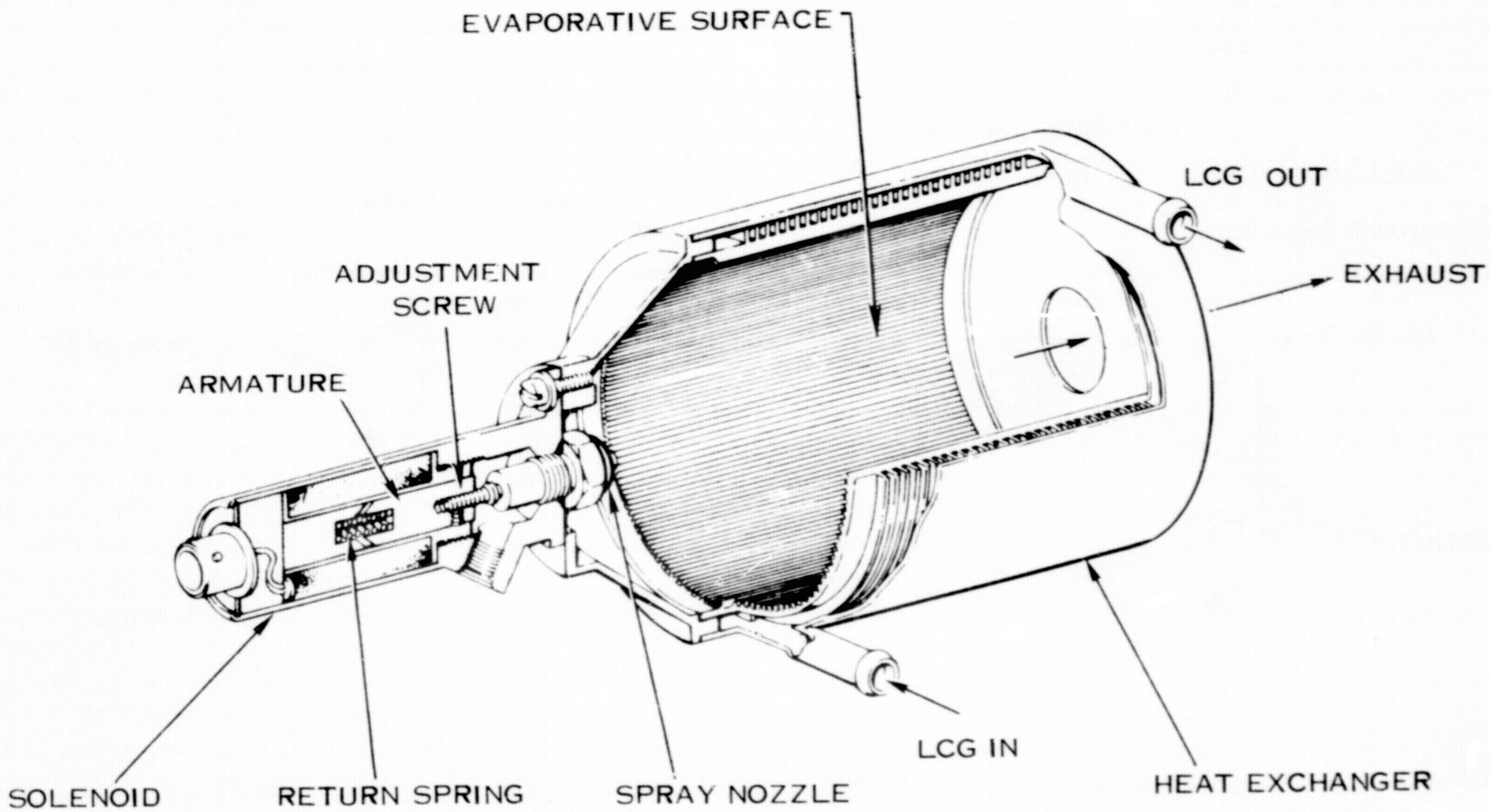

FIGURE 4–2–5
SPRAYING FLASH EVAPORATOR WITH TWO FLUID HEAT EXCHANGER

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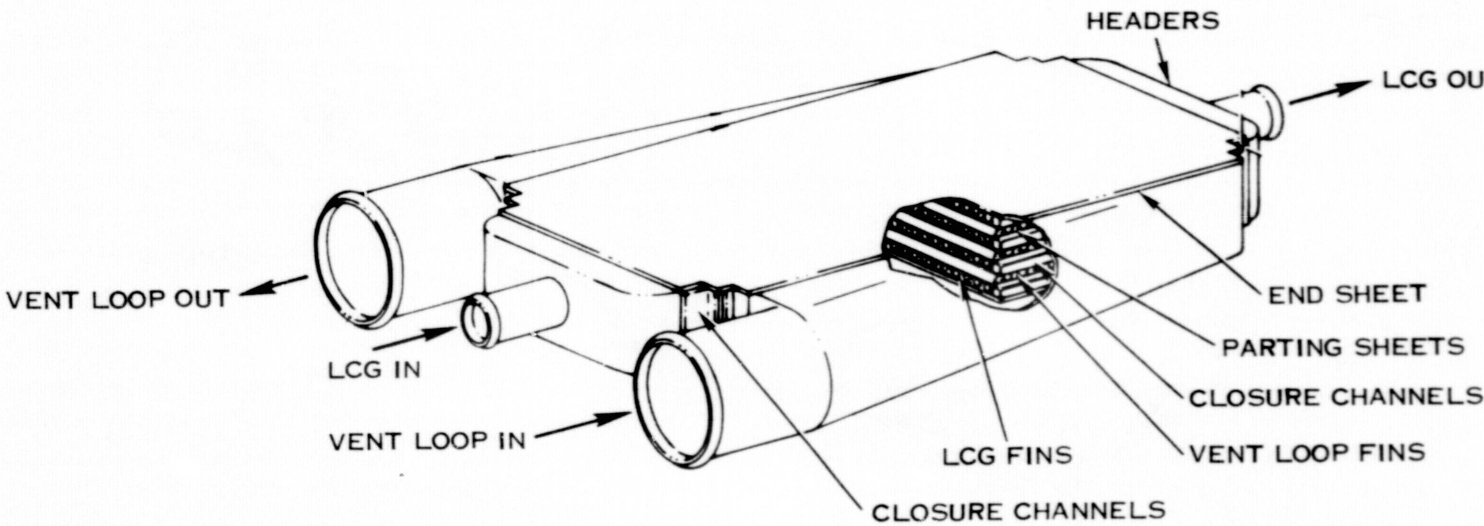

FIGURE 4–2–6

TWO–FLUID STAINLESS STEEL HEAT EXCHANGER

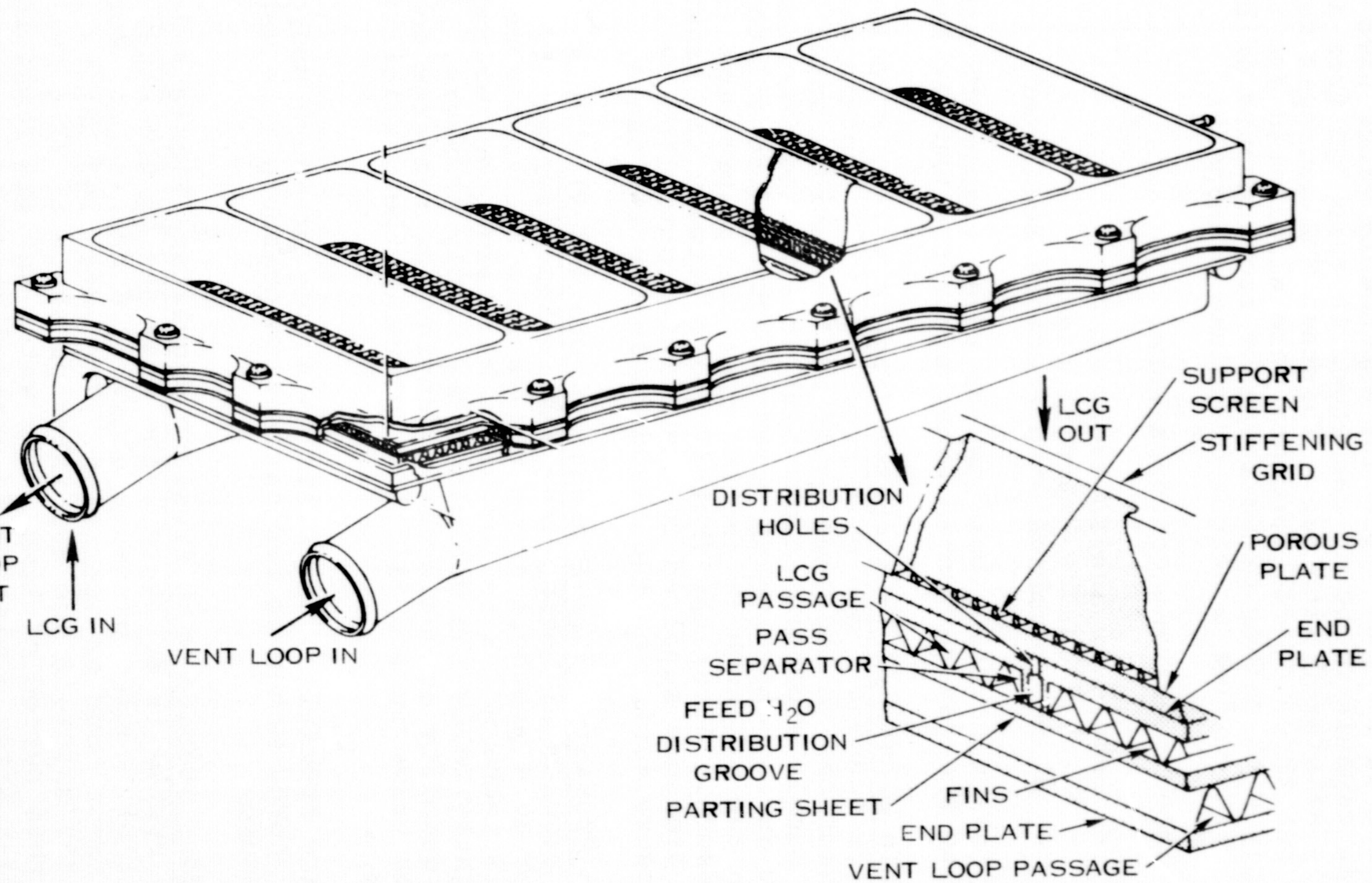

FIGURE 4–2–7
THREE FLUID SUBLIMATOR

4.2.3 Water Management Subsystem (WMS)

The WMS is used to store the expendable water used by the HRS. It is capable of being recharged in zero "g" from a water supply fully saturated with gas. Thirteen WMS concepts were considered. All but three of the concepts were eliminated due to failure to comply with safety or performance requirements or by being non-competitive from a weight or volume standpoint.

The three remaining concepts were:

- Bubble Expansion Tank
- High Pressure Water Storage
- Bladder Storage with Pressure Regulator

The following describes how the three viable WMS candidates accommodate the gas saturated water after the WMS has been recharged.

Bubble Expansion Tank System (Figure 4-2-8) - Following the recharge sequence, the main reservoir will contain water and gas pressurized to the same level as the vehicle water supply system. The bubble expansion tank which is isolated from the main reservoir during charging is sized to accommodate all the gas released when the pressure is reduced from charge pressure to operating pressure. After the shutoff valve between the tanks is opened, the pressure supplied to the HRS is controlled by the vent loop pressure acting on the bladders in the two tanks.

High Pressure Water Storage (Figure 4-2-9) - This concept avoids the problem of having free gas in the reservoir by storing the water at a pressure above the vehicle fill pressure. During EVLSS recharge, a relief valve maintains the reservoir pressure slightly below the vehicle water supply pressure. This minimizes the quantity of gas evolving during the recharge sequence. A check valve in the fill line prevents the possibility of back flow.

During operation, the EVLSS O_2 supply pressure source pressurizes the stored water at its saturation pressure (the vehicle supply pressure).

Bladder Storage with Pressure Regulator (Figure 4-2-10) - When this system is activated, the free gas in the water maintains the reservoir outlet pressure above 27.6 KPa (4 psi) for approximately the first hour of operation. The water regulators in the line to the HRS maintain the HRS inlet pressure at 27.6 KPa (4 psi) during this period of time. The water and gas remaining in the bladder after a mission is drained prior to recharge to minimize

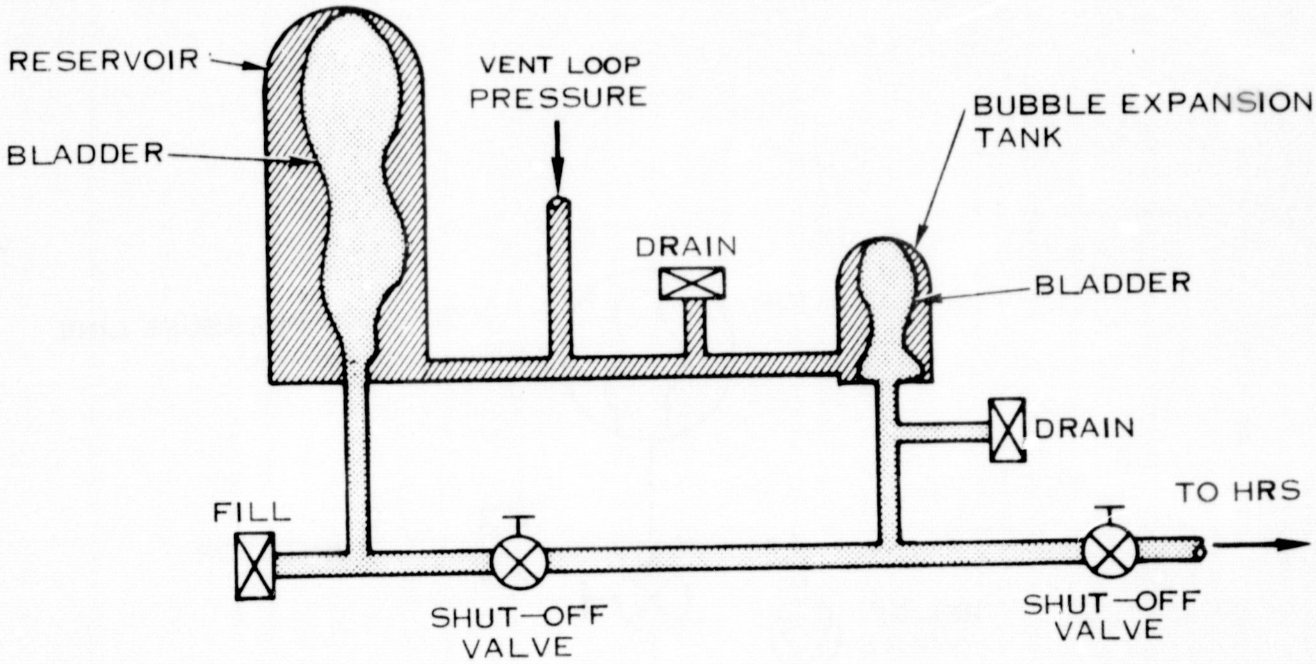

FIGURE 4-2-8
BUBBLE EXPANSION TANK WMS CONCEPT

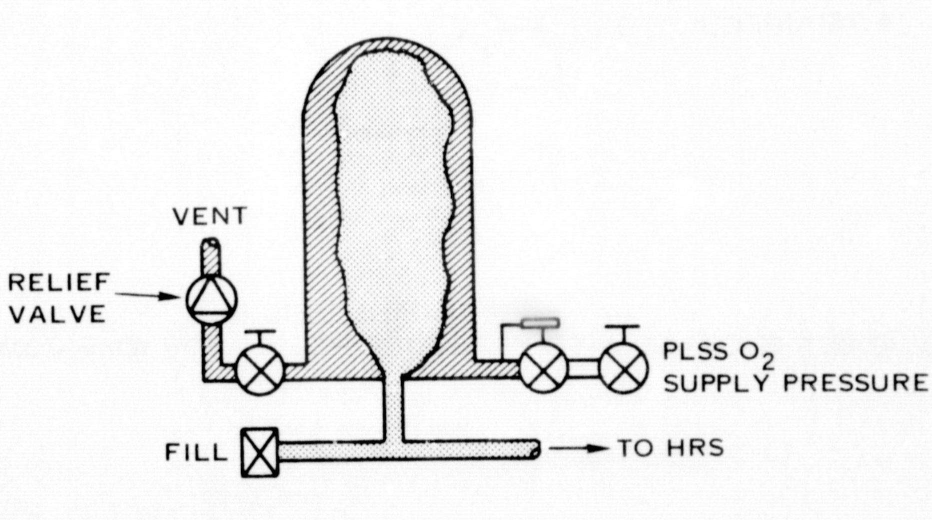

FIGURE 4-2-9
HIGH PRESSURE WATER STORAGE WMS CONCEPT

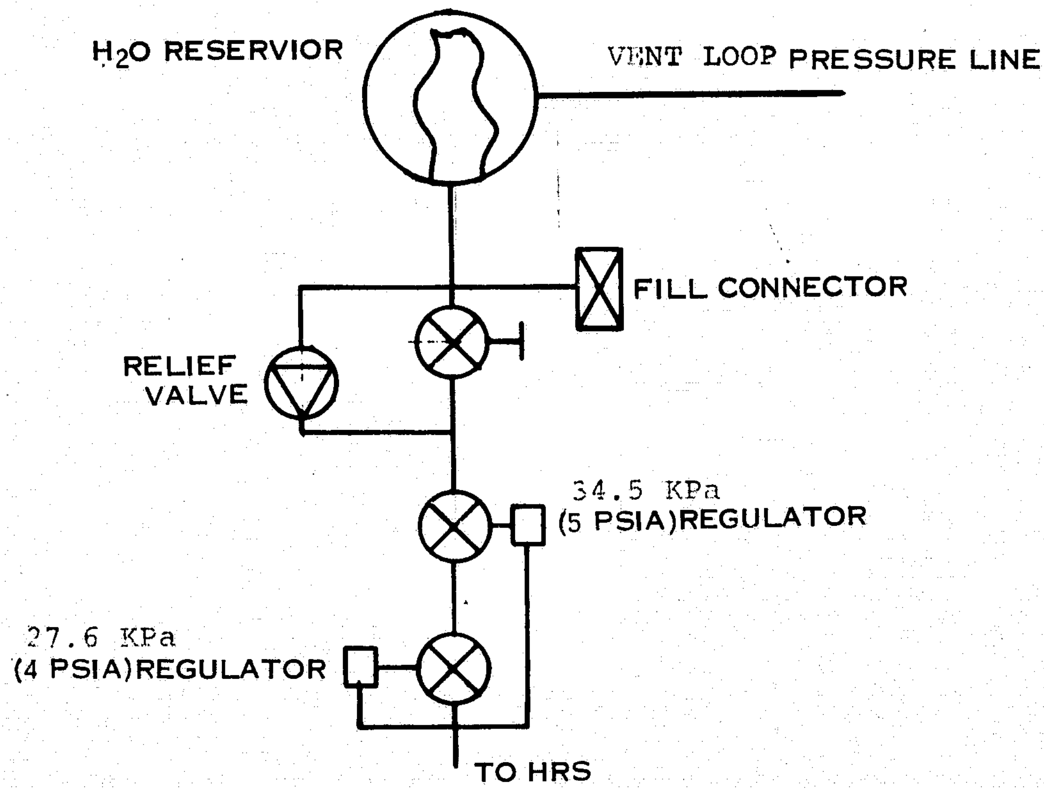

FIGURE 4-2-10
BLADDER STORAGE WITH PRESSURE REGULATOR WMS CONCEPT

4.2.3 (Continued)

the reservoir size. This system is only compatible with the sublimator since the flash evaporator requires a pressure above 206 KPa (30 psi).

The three WMS concepts described above were used to define the TCS concepts for final evaluation.

4.2.4 Humidity Control Subsystem

The HCS is used to control the water which condenses in the vent loop portion of the HRS. It must collect the condensate, separate it from the vent loop gas, and pump it into the condensate storage equipment.

Nine HCS concepts which utilized one or more of the following water separating devices were evaluated.

Rotary Separator (Figure 4-2-11) - The rotary separator consists of a shaft mounted drum assembly, an impact pitot and a housing to encapsulate the drum. The rotational motion of the drum induces gas/liquid separation. Entrained moisture in the incoming gas stream is forced by centripetal acceleration into a trough at the outer periphery of the drum, and the gas stream returns to the vent loop. The pressure at the pitot is the sum of the pressure energy due to water impacting the pitot plus the static pressure developed by rotating the water in the drum. When the water pressure in the pitot exceeds the cracking pressure of a back pressure valve located in the outlet line, the water is pumped into the storage container.

Fan Separator (Figure 4-2-12) - The fan separator is basically a rotary separator with a fan rotor mounted on the same drive shaft.

Elbow Wick Separator (Figure 4-2-13) - The elbow wick separator consists of a bladder, a sponge-like wick and a housing containing inlet and outlet ducts, a drain line and a pressure port. The flow passage through the wick makes several turns to induce water separation from the gas stream by momentum change. The separator permits draining of the condensate at the end of each EVA by pressurizing the bladder to squeeze the wick. This is accomplished by closing valves in the inlet and outlet ducts, connecting a drain fitting to the drain line and pressurizing the back side of the bladder through the pressure port. After draining, the drain fitting is disconnected, the inlet and outlet duct valves are open, and the pressure port is vented to ambient.

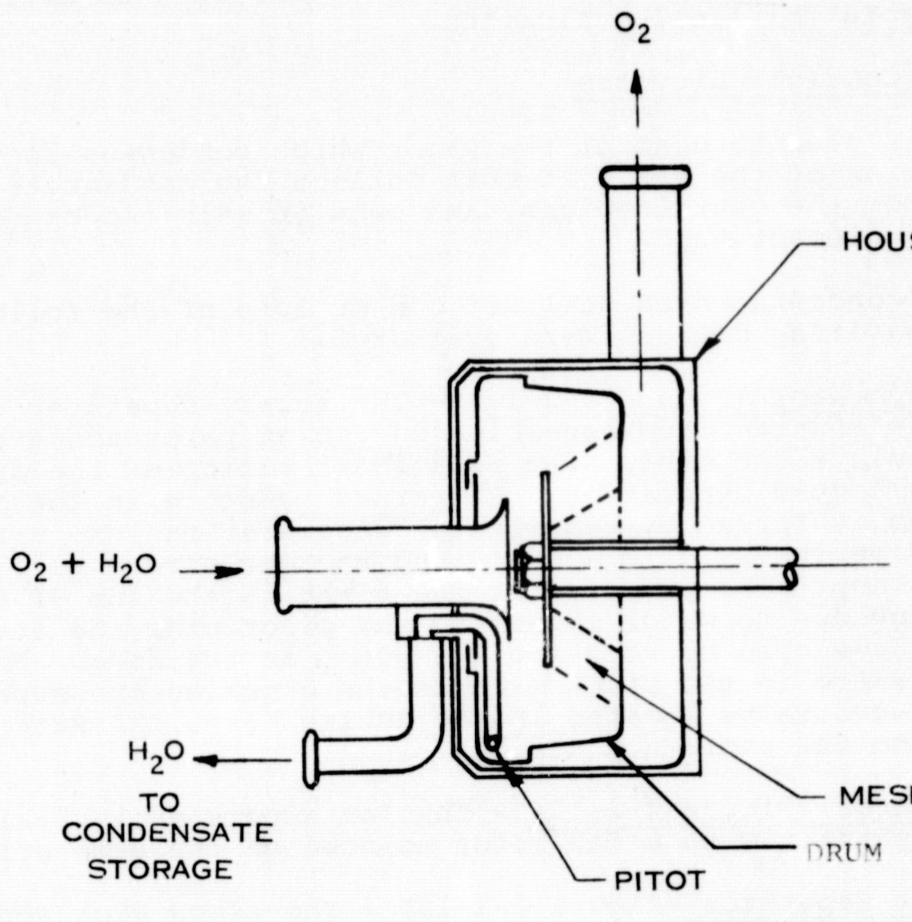

FIGURE 4-2-11
ROTARY SEPARATOR

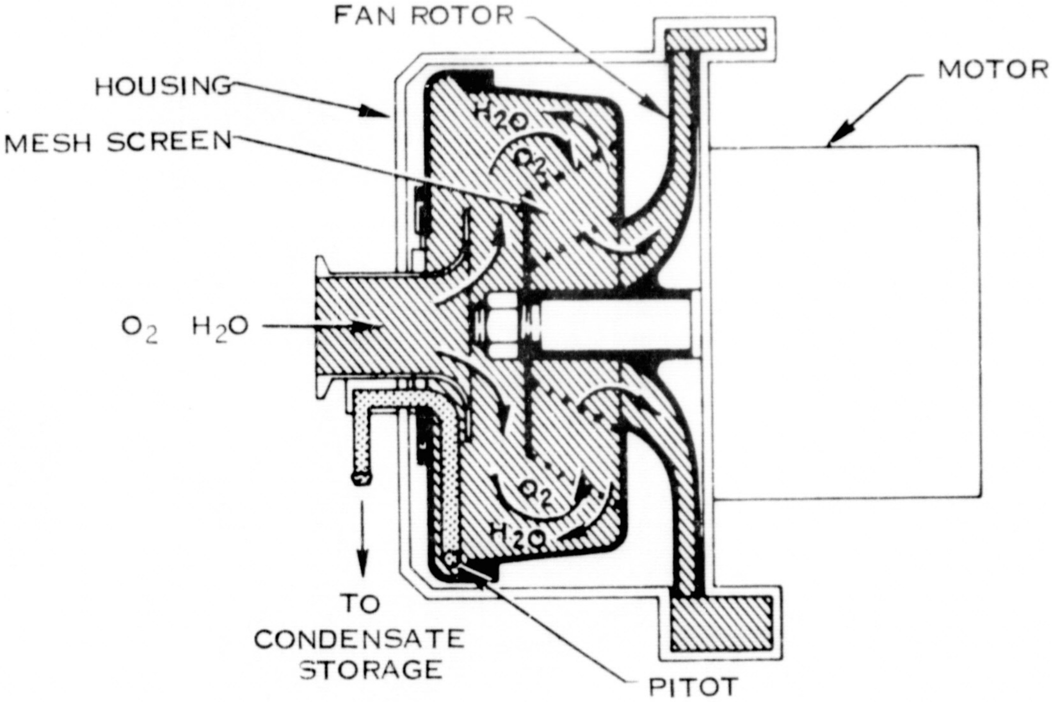

FIGURE 4–2–12
FAN SEPARATOR

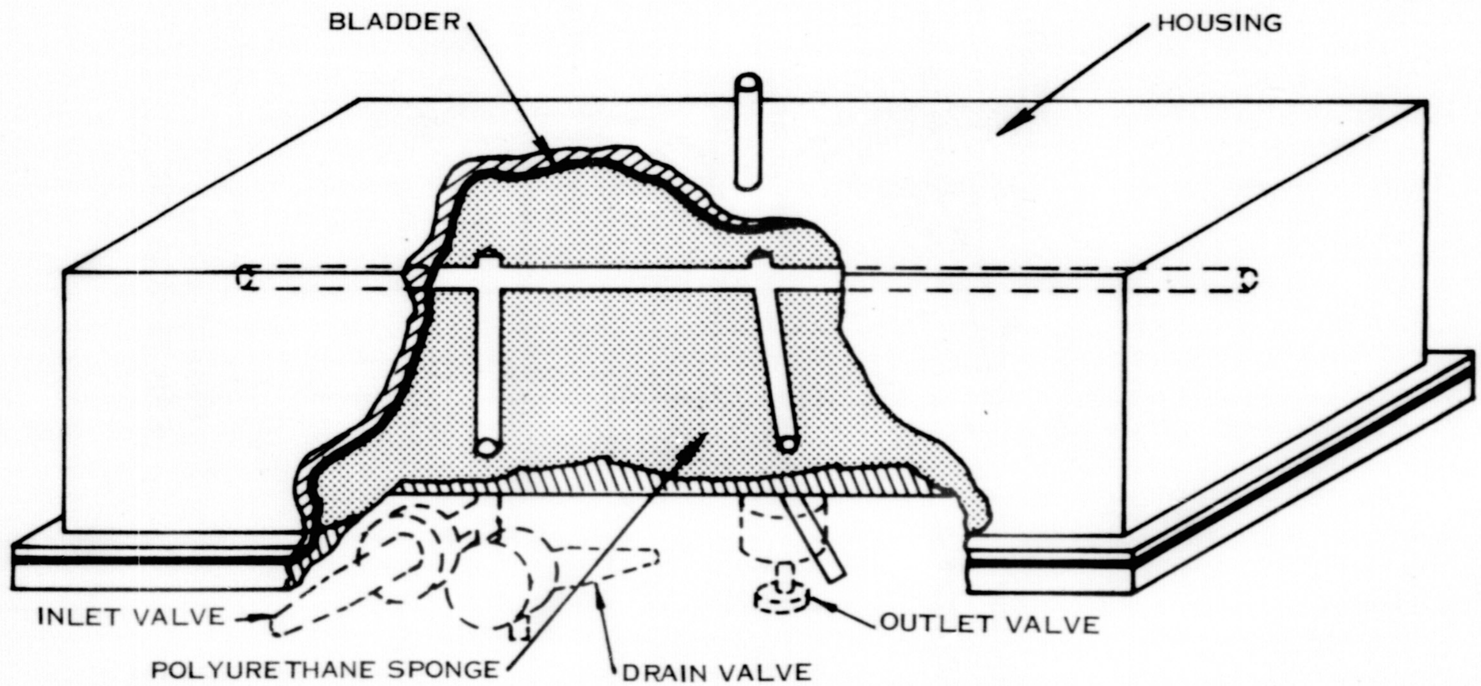

FIGURE 4–2–13
WICK SEPARATOR

4.2.4 (Continued)

Elbow Scupper (Figure 4-2-14) - The elbow scupper consists of an elbow, an O_2 outlet duct and a water duct. The scupper isolates and traps condensate from the gas stream by a change in momentum imposed by turning the flow in the elbow. The water free gas is returned to the vent loop via the O_2 outlet duct. The separated water collects in an annulus where it and approximately 5% of the O_2 is transferred to a second separating device for further processing.

Slurper (Figure 4-2-15) - The slurper consists of a series of bleed holes located within the outlet passage of the condensing circuit of the heat exchanger and are manifolded to a common header. The slurper header pressure is maintained below the condensing circuit pressure; thus, when water condenses and blocks the bleed holes, the pressure differential across the holes draws the water into the manifold which is connected to a second separating device for further processing.

Absorbtion by a Desiccant (Figure 4-2-16) - This device consists of a desiccant container filled with silica gel and a cooling coil. The gas and free water is introduced at one end of the bed and as the gas passes through the bed, the water is absorbed by the silica gel. The heat of absorption is removed by the cooling water.

Of the nine HCS concepts considered, only two were eliminated by evaluation at the subsystem level. The seven remaining concepts are listed below and are shown schematically in Figures 4-2-17 through 4-2-23.

- Single Stage Rotary Separator
- Single Stage Elbow Wick Separator
- First Stage Scupper/Second Stage Fan/Separator
- First Stage Scupper/Second Stage Rotary Separator
- First Stage Scupper/Second Stage Wick Storage
- First Stage Slurper/Second Stage Rotary Separator
- First Stage Slurper/Second Stage Wick Separator

4.2.5 LCG Pressure Control

The pressure in the liquid cooling circuit must be maintained at a pressure equal to or greater than the suit pressure. The LCG pressure control device is used to provide makeup for water lost by leakage or spillage and to maintain the water pressure above the minimum allowed. Three concepts were considered of which, after evaluation, two were retained for consideration at the system level. These were use of the expendable water circuit as shown in Figure 4-2-24 and use of a pressure loaded accumulator as shown in Figure 4-2-25.

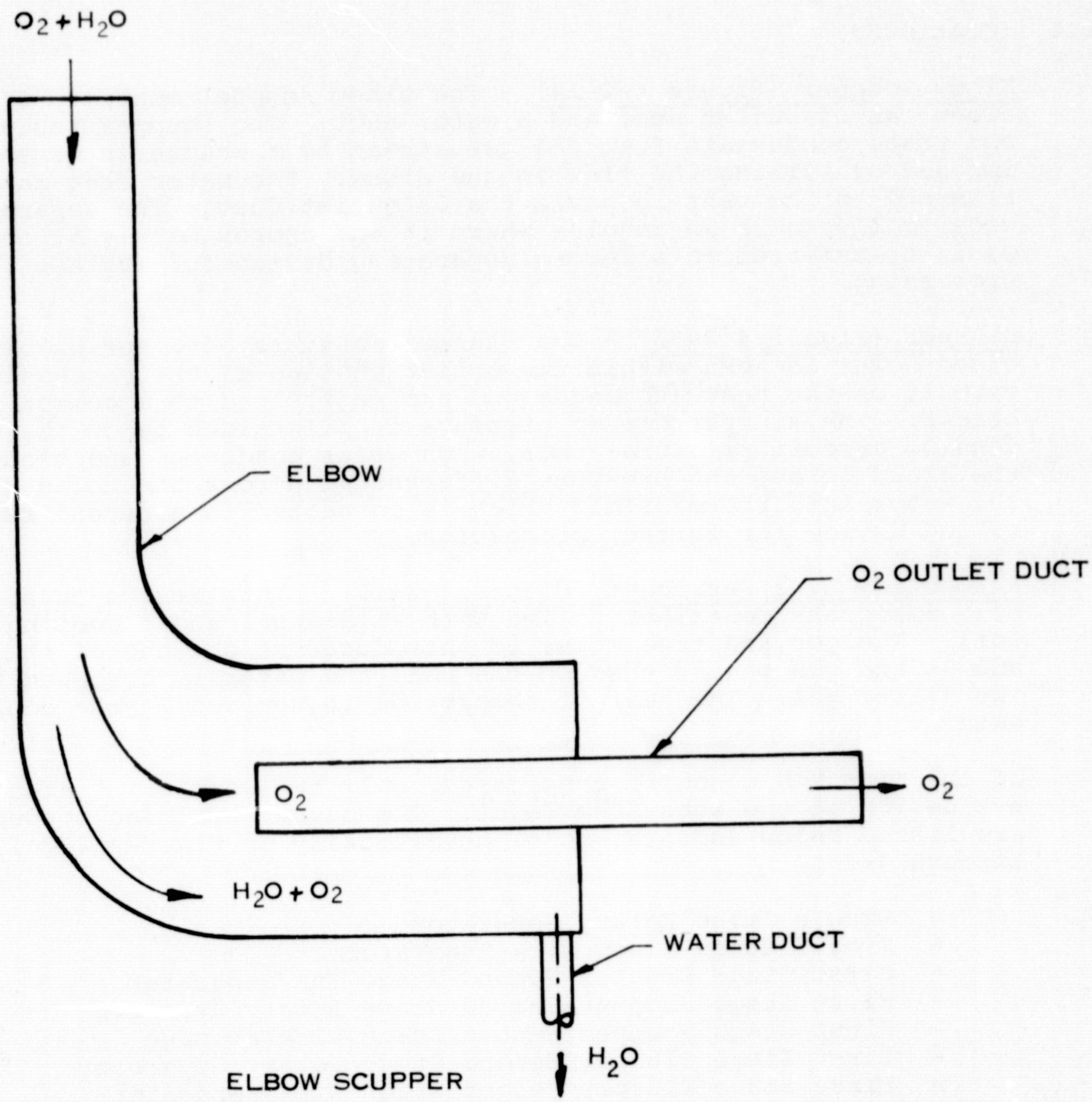

FIGURE 4-2-14
SIMPLIFIED ELBOW SCUPPER

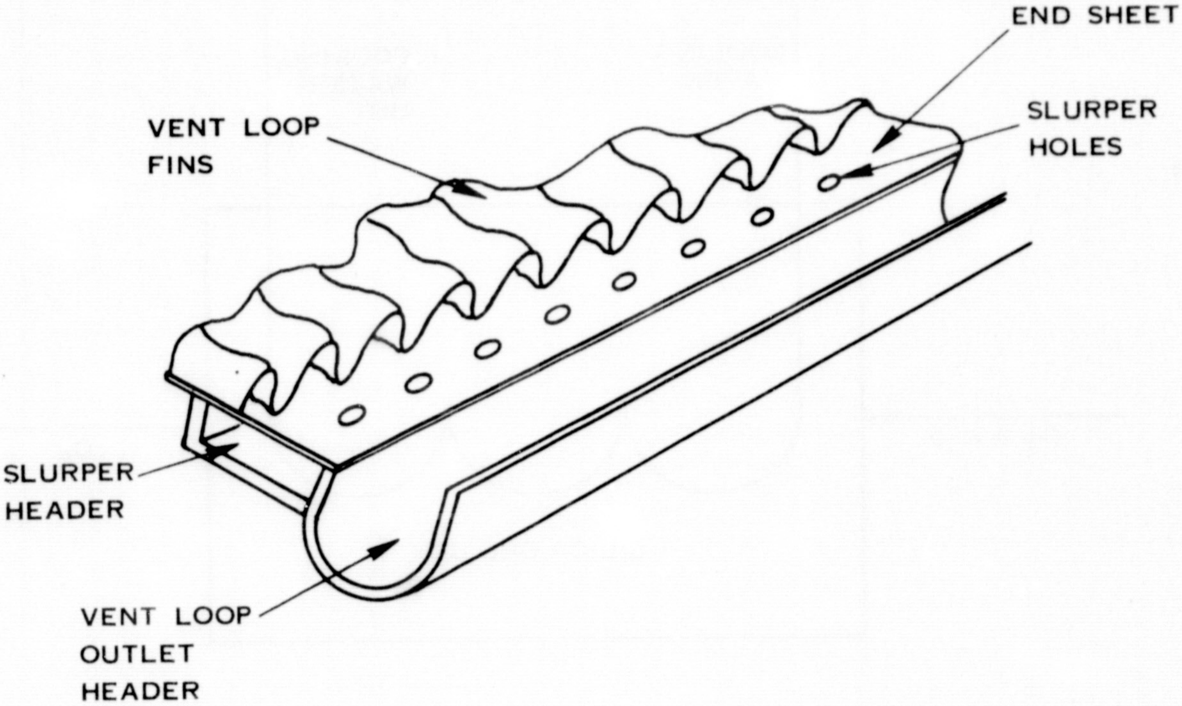

FIGURE 4–2–15
SLURPER

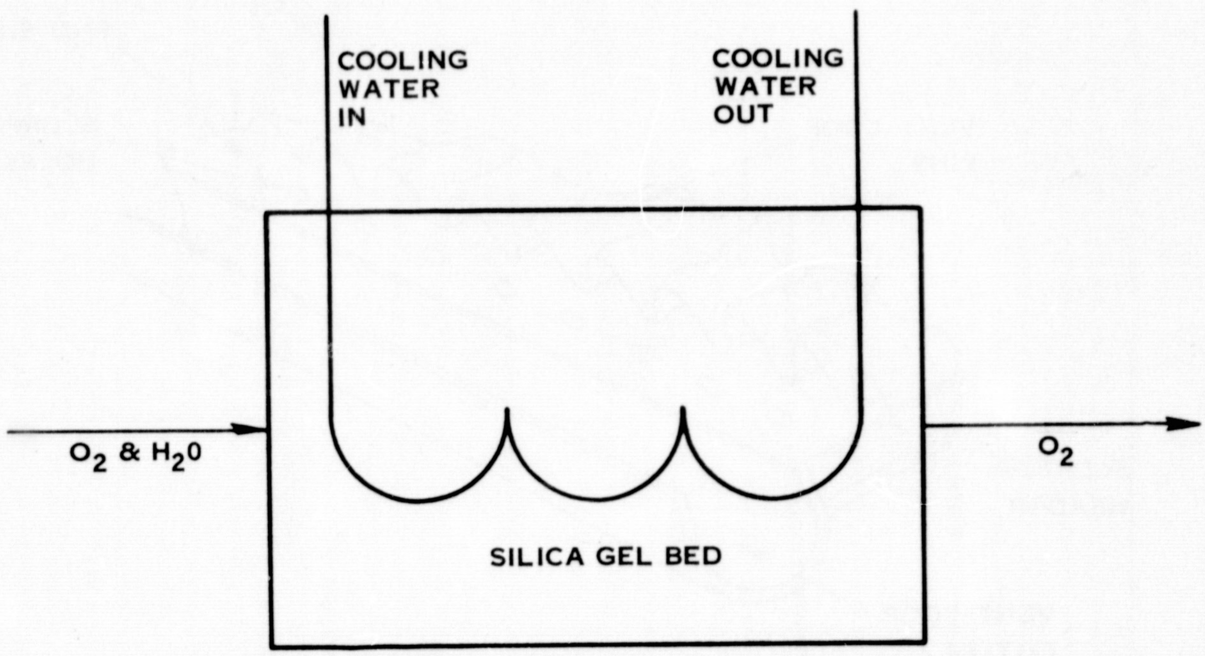

FIGURE 4–2–16
ABSORBTION BY A DESICCANT

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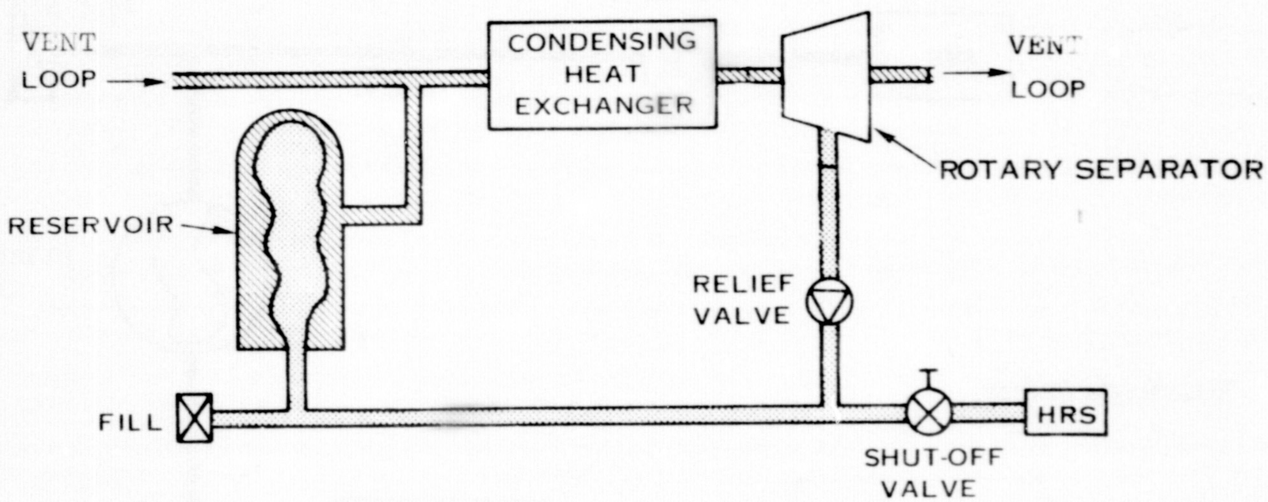

FIGURE 4–2–17
SINGLE STAGE ROTARY SEPARATOR

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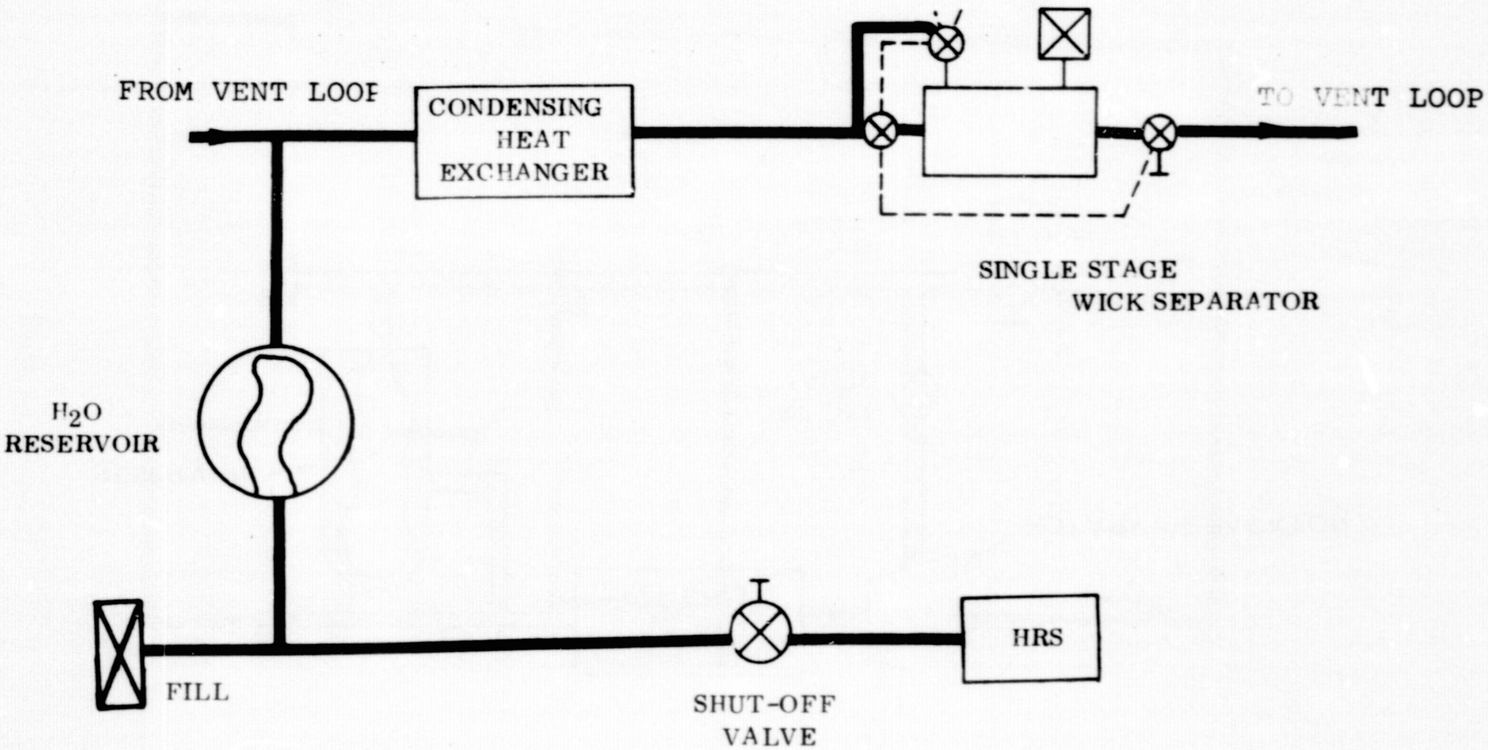

FIGURE 4–2–18
SINGLE STAGE ELBOW WICK SEPARATOR

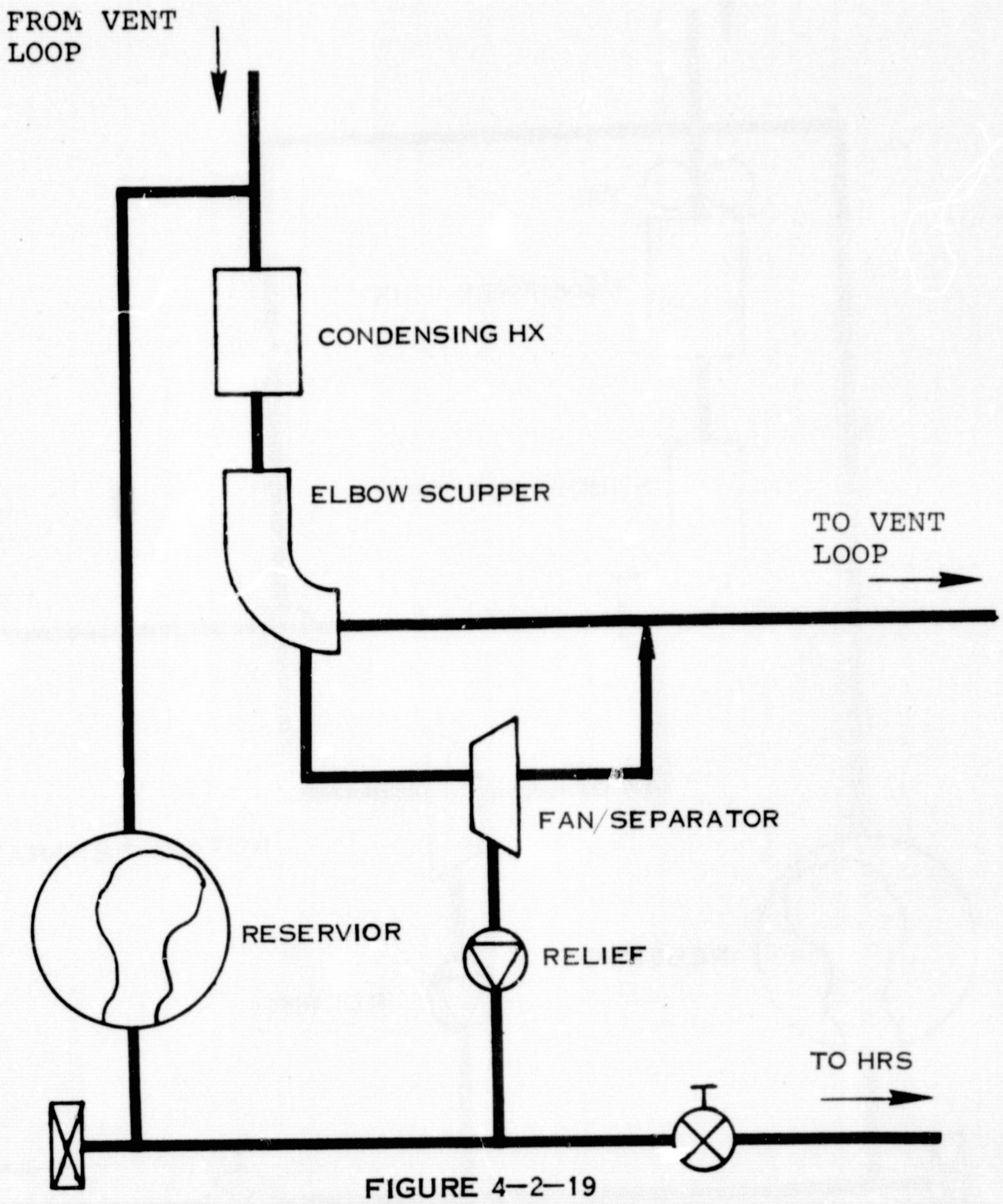

FIGURE 4-2-19
FIRST STAGE SCUPPER/2ND STAGE FAN/SEPARATOR

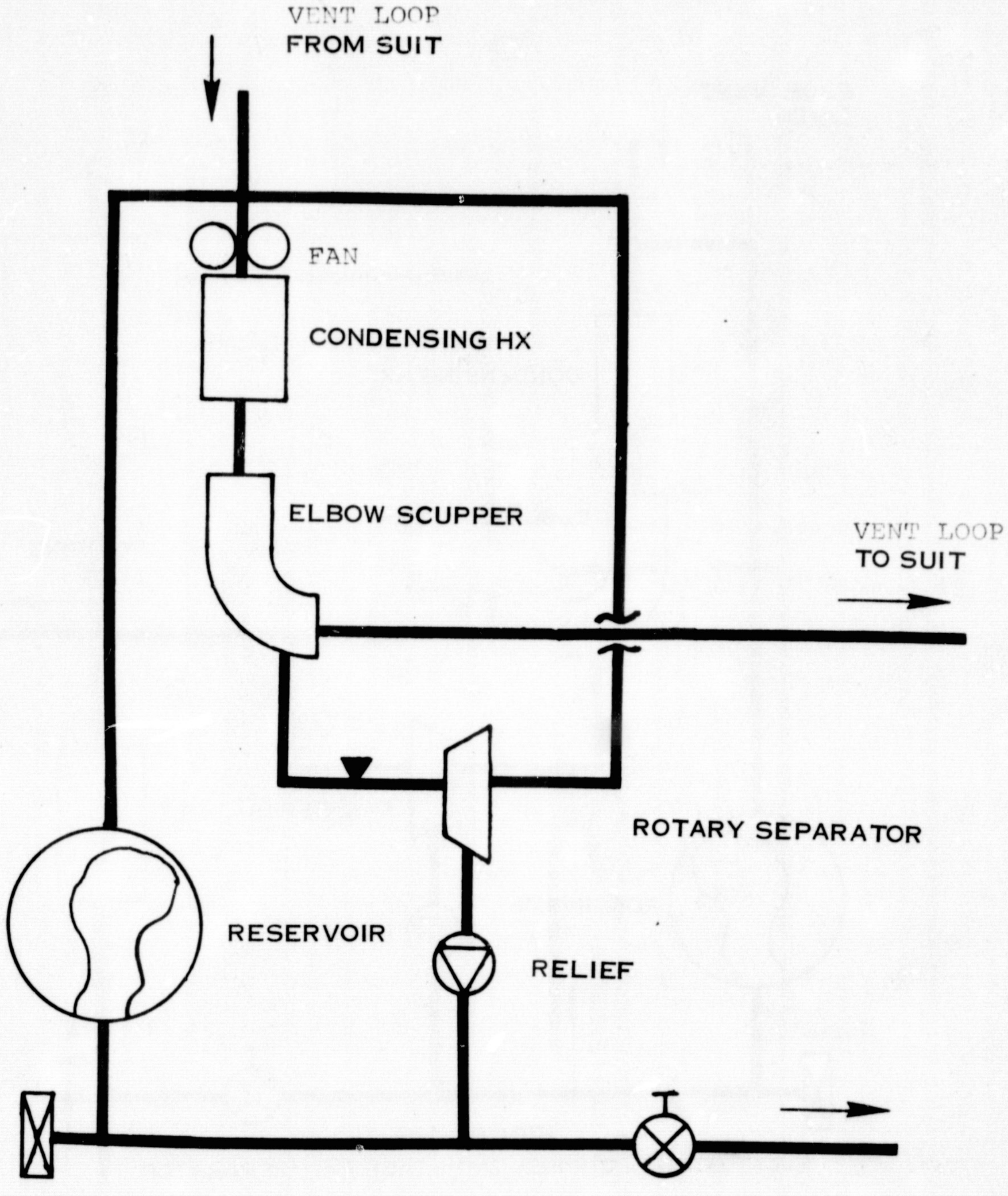

FIGURE 4-2-20
FIRST STAGE SCUPPER/ SECOND STAGE ROTARY SEPARATOR

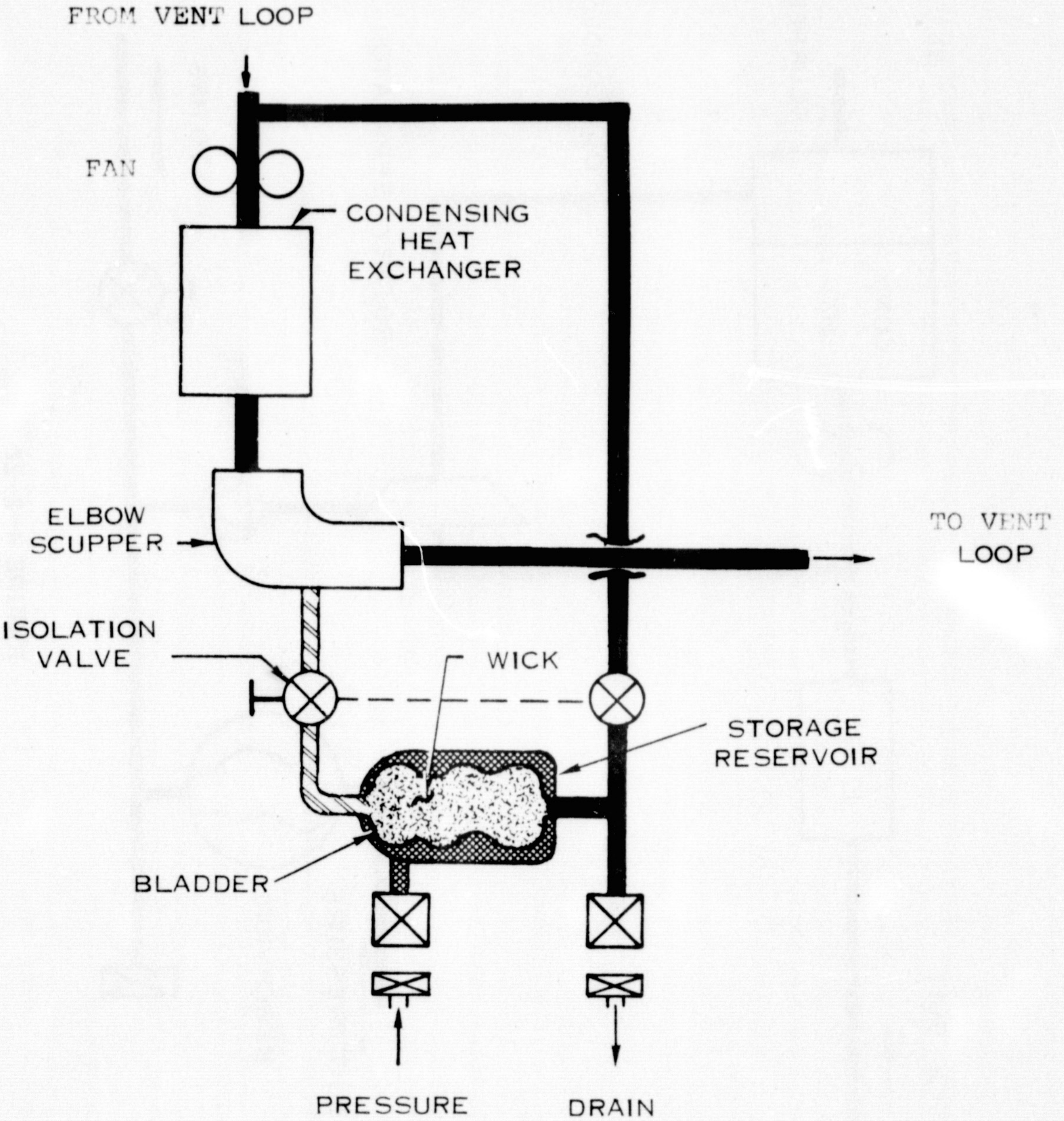

FIGURE 4-2-21
FIRST STAGE SCUPPER, SECOND STAGE WICK STORAGE

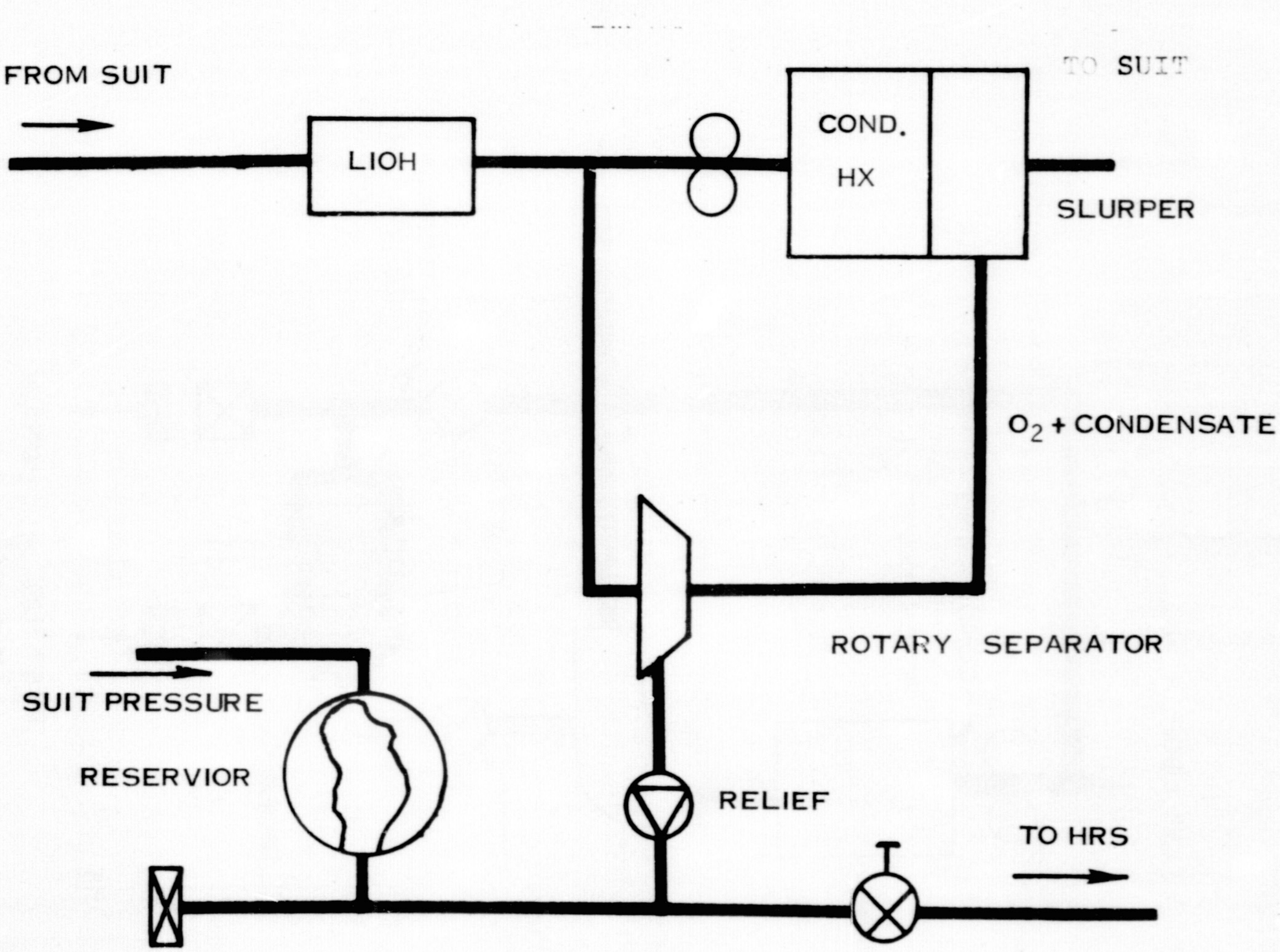

FIGURE 4–2–22
FIRST STAGE SLUPPER/ SECOND STAGE ROTARY SEPARATOR

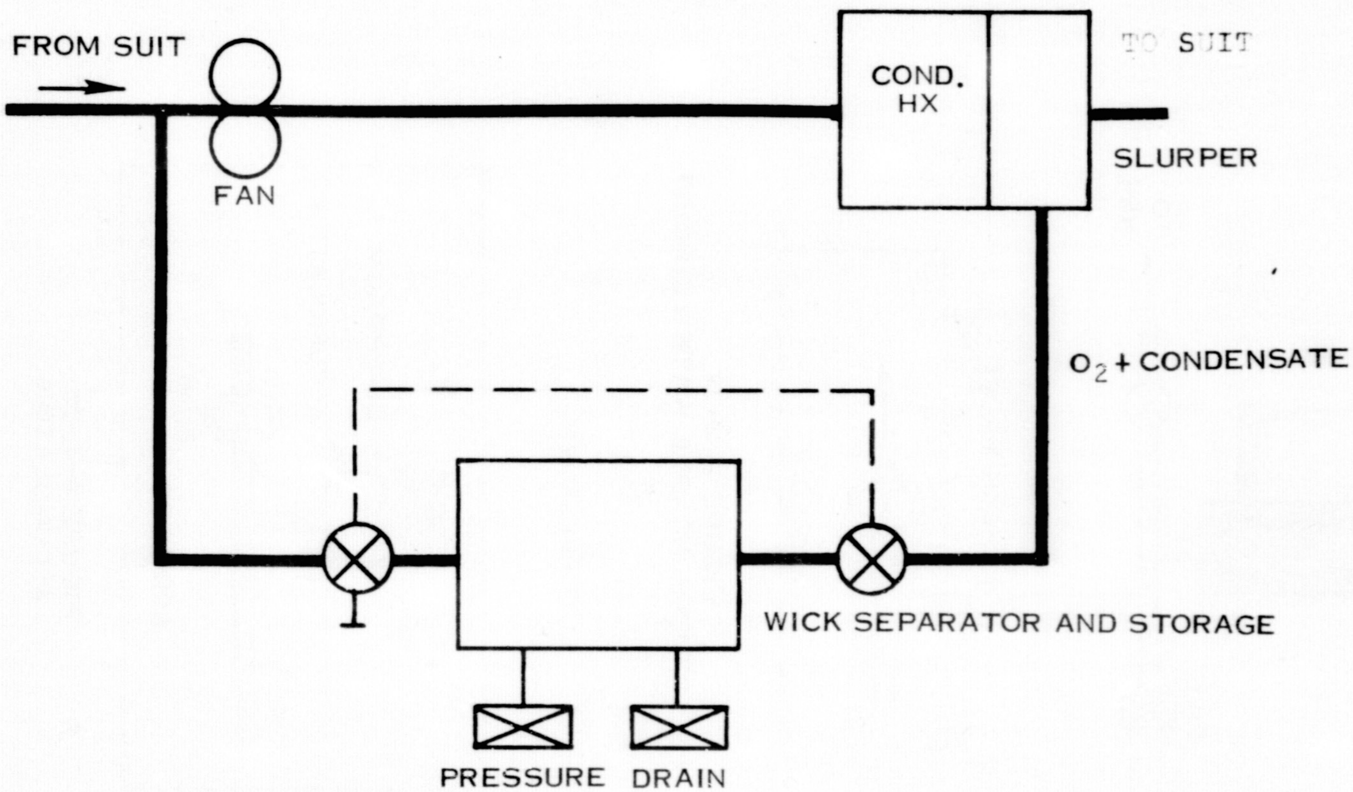

FIGURE 4–2–23
FIRST STAGE SLURPER/SECOND STAGE WICK SEPARATOR

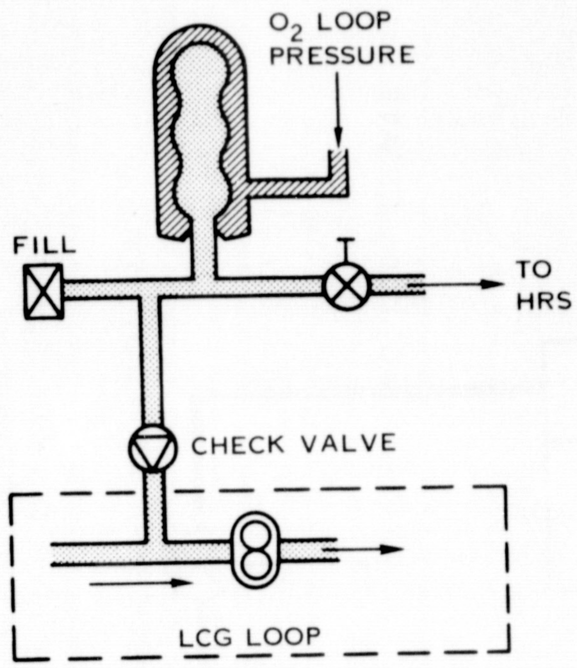

FIGURE 4-2-24
USE OF EXPENDABLE WATER CIRCUIT

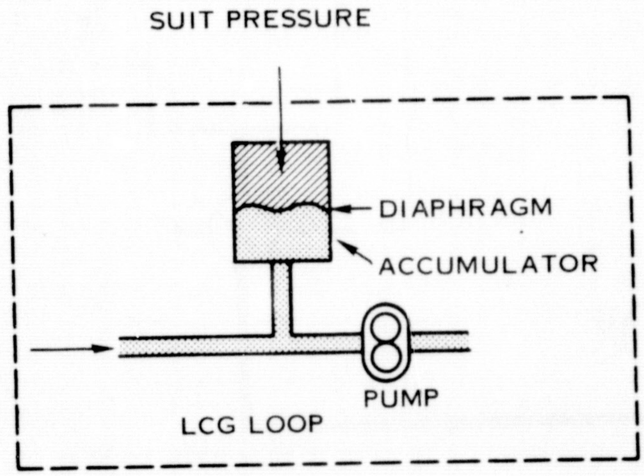

FIGURE 4-2-25
ACCUMULATOR

4.2.6 LCG Temperature Control

The LCG is used to cool the crewman and since the crewman expends effort at different work rates, the amount of cooling provided must be controllable in order to maintain thermal comfort. The five LCG temperature control concepts listed below were evaluated.

- LCG Inlet Temperature Control
- LCG Inlet Flow Control
- LCG Loop Flow Control
- HRS Outlet Temperature Control
- Feed Water Flow Control

Of these, the LCG inlet flow control shown in Figure 4-2-26 was identified as the optimum means of providing LCG thermal control.

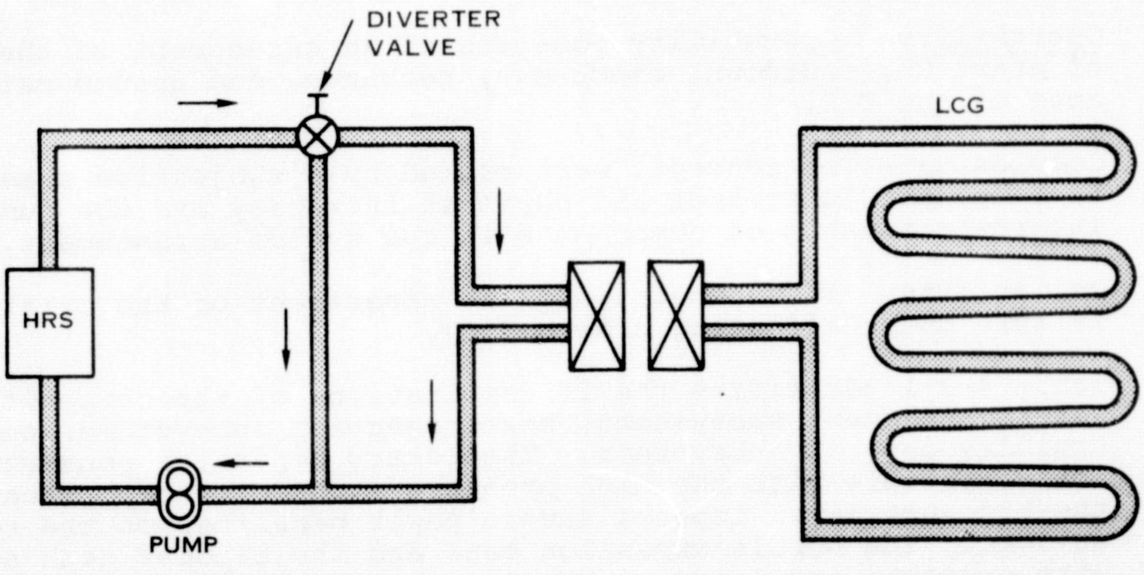

FIGURE 4-2-26
LCG INLET FLOW CONTROL

4.2.7 Thermal Control System Evaluation

The two competitive heat rejection subsystems, the three water management subsystems, the seven humidity control subsystems, and the LCG pressure and temperature control concepts were combined to form the candidate thermal control systems. Only systems which could meet the TCS performance requirements were considered.

The evaluation was conducted on the basis of the following relative criteria.

Vehicle Launch Weight - Vehicle launch weight consists of the summation of the weight of two EVLSS's launched dry, the vehicle power penalty based on .87 Kg/kwh (1.92 lbs/kwh) and six dual EVA's.

EVLSS Volume - EVLSS volume is the summation of the estimated component and packaging hardware volumes.

Program Cost - Program cost consists of a relative assessment of the ground maintenance cost for each flight, the design and development cost, the cost of 18 sets of TCS hardware, and the vehicle weight penalty based on a cost of $35,000/lb.

Operability - Operability consists of an assessment of the ease of start up, shutdown, check out, recharge, and ground maintenance of the TCS.

Complexity - The concepts were ranked by a subjective assessment of component functional and physical intricacy and the number and interrelationship of components in the system arrangement.

Reliability - This consisted of an assessment of the critical failure modes affecting crew safety.

Table 4-2-1 identifies the 16 combinations of the competitive water management subsystems, heat rejection subsystems, and humidity control subsystems. The rotary separator concepts are not compatible with the high pressure storage concept because the pressure level imposes severe power penalties on the rotary devices. The bubble expansion tank and the bladder tank storage with pressure regulator concepts are not compatible with the flash evaporator because a minimum of 207 KPa (30 psi) is required for operation.

WATER MANAGEMENT SUBSYSTEM	HUMIDITY CONTROL SUBSYSTEM							HEAT REJECTION SUBSYSTEM
	SINGLE STAGE MOTOR ROTARY SEPARATOR	SINGLE STAGE ELBOW WICK SEPARATOR	1ST STAGE SCUPPER 2ND FAN SEPARATOR	1ST STAGE SCUPPER 2ND STAGE MOTOR ROTARY SEPARATOR	1ST STAGE SCUPPER/ 2ND STAGE WICK STORAGE	1ST STAGE SLURPER 2ND STAGE MOTOR/ ROTARY SEPARATOR	1ST STAGE SLURPER 2ND STAGE WICK STORAGE	
BUBBLE EXPANSION TANK	1	2	3	4	5	6	7	SUBLIMATOR
HIGH PRESSURE STORAGE	NO	8	NO	NO	9	NO	10	
BLADDER TANK STORAGE WITH PRESSURE REG	NO	11	NO	NO	12	NO	13	
BUBBLE EXPANSION TANK	NO	NO	NO	NO	NO	NO	NO	FLASH EVAPORATOR
HIGH PRESSURE STORAGE	NO	14	NO	NO	15	NO	16	
BLADDER TANK STORAGE WITH PRESSURE REG	NO	NO	NO	NO	NO	NO	NO	

TABLE 4—2—1
TCS SYSTEMS

4.2.7 (Continued)

Figures 4-2-27 and 4-2-28 respectively show the ratings for vehicle launch weight and EVLSS volume. In establishing the rating, any concept within 10% of the least weight or volume concept was given a rating of 1. Those concepts between 10 and 20% were rated 2 and so on. The relative cost shown in Figure 4-2-29 was established based on an assessment of the nonrecurring cost to design and develop a concept, the cost to fabricate 18 units, a moderate allowance for replacement of limited life items, and the vehicle weight penalty cost. The rating was for any system within 10% of the least cost system was 1, for systems within 20%, the rating was 2, and for those within 30%, the rating was 3. It should be noted that almost all of the systems were within 20% of the least expensive, so cost alone could not be considered a driving factor.

Operability was an assessment of the ease of start up, shutdown, check out, recharge, and ground maintenance of the TCS. There was no significant difference in the ground maintenance identified, all concepts required between 9 and 11 steps for recharge and start up and shutdown procedures were approximately the same for all concepts. The rating was established on the number of recharge steps. Because of the small differences between systems, it was necessary to prevent operability from being a driving factor in the concept selection. Thus, ratings of .1, .2, and .3 were used as summarized in Figure 4-2-30.

The concepts had between 15 and 19 components of which many were common or similar. For example, all systems had a water reservoir, relief valves, and shutoff valves, and the bubble expansion tank was similar to the accumulator while the flash evaporator heat exchanger, plus the separate two fluid heat exchanger was essentially equivalent to the sublimator. Thus, the complexity rating was established by considering the non-common components which were more complex than a simple shutoff valve or relief valve. For this evaluation, motor electronics, controller electronics, and oxygen regulators were given a rating of 2, while the mechanical portion of a motor, a wick separator, a rotary separator, a flash evaporator nozzle solenoid valve, and a 3 way valve were given a rating of 1. Table 4-2-2 lists the concepts, the components considered, and the total component rating. The component ratings were converted to system ratings as follows.

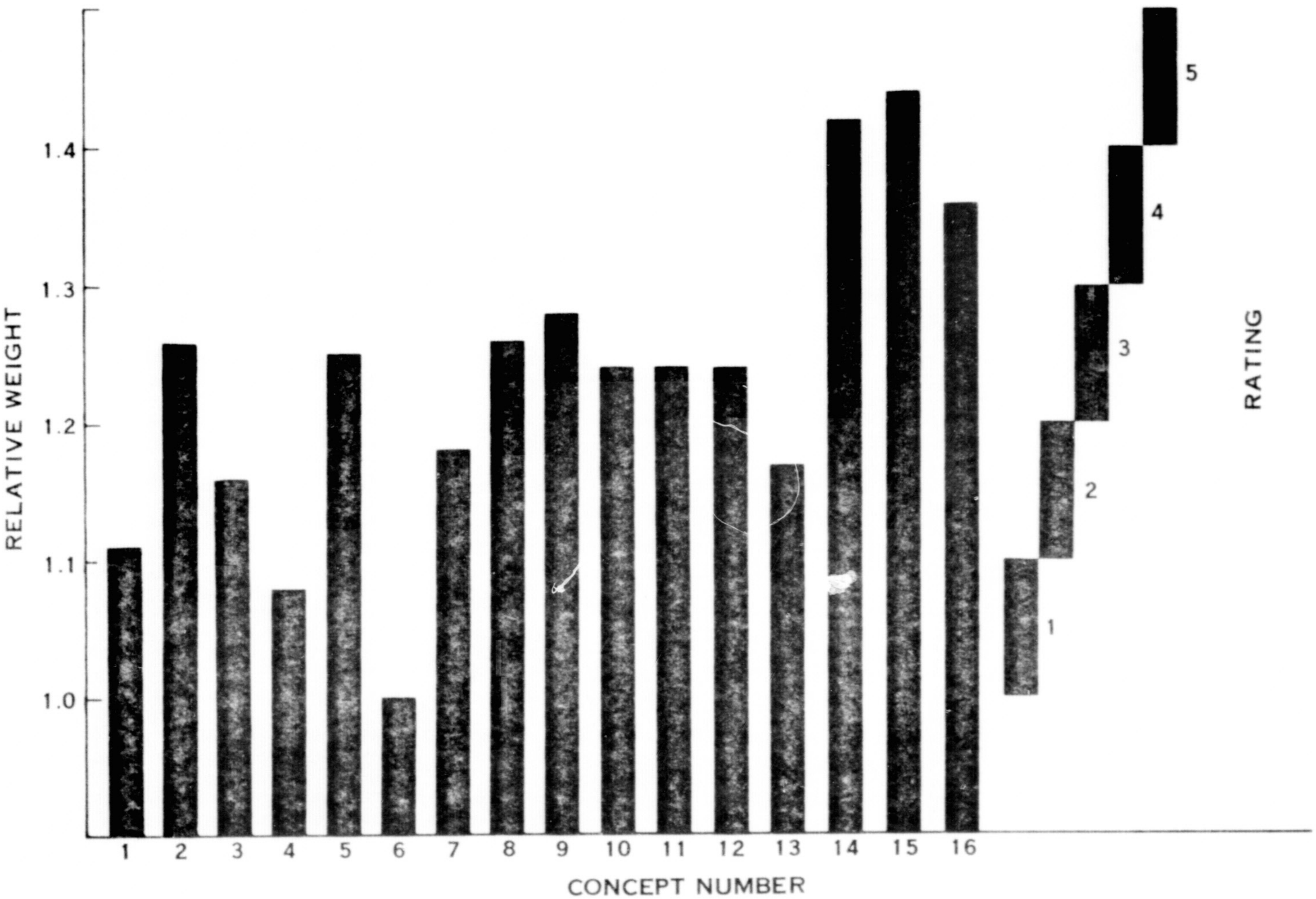

FIGURE 4–2–27 VEHICLE LAUNCH WEIGHT RATING

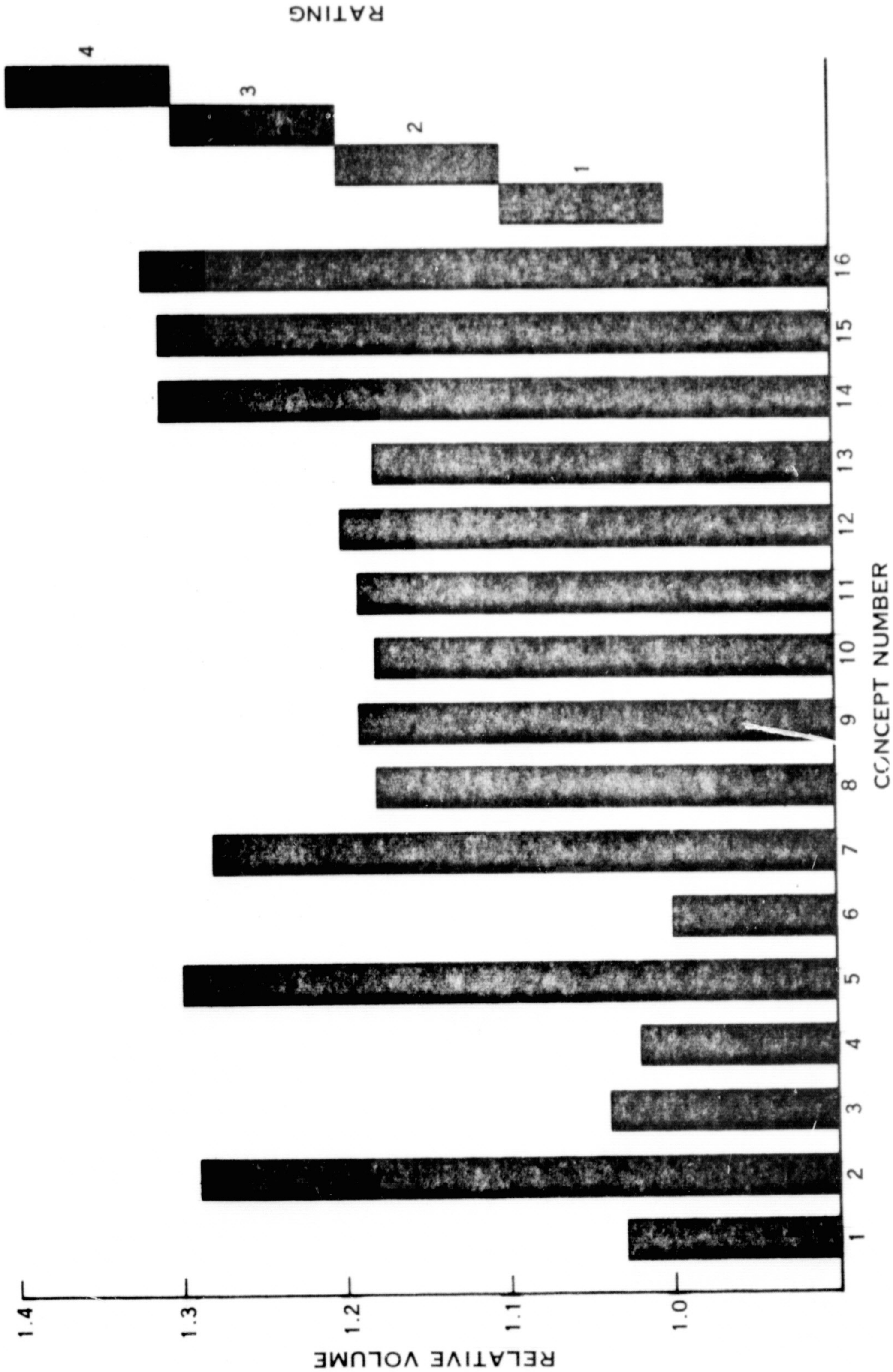

FIGURE 4–2–28 EVLSS VOLUME RATING

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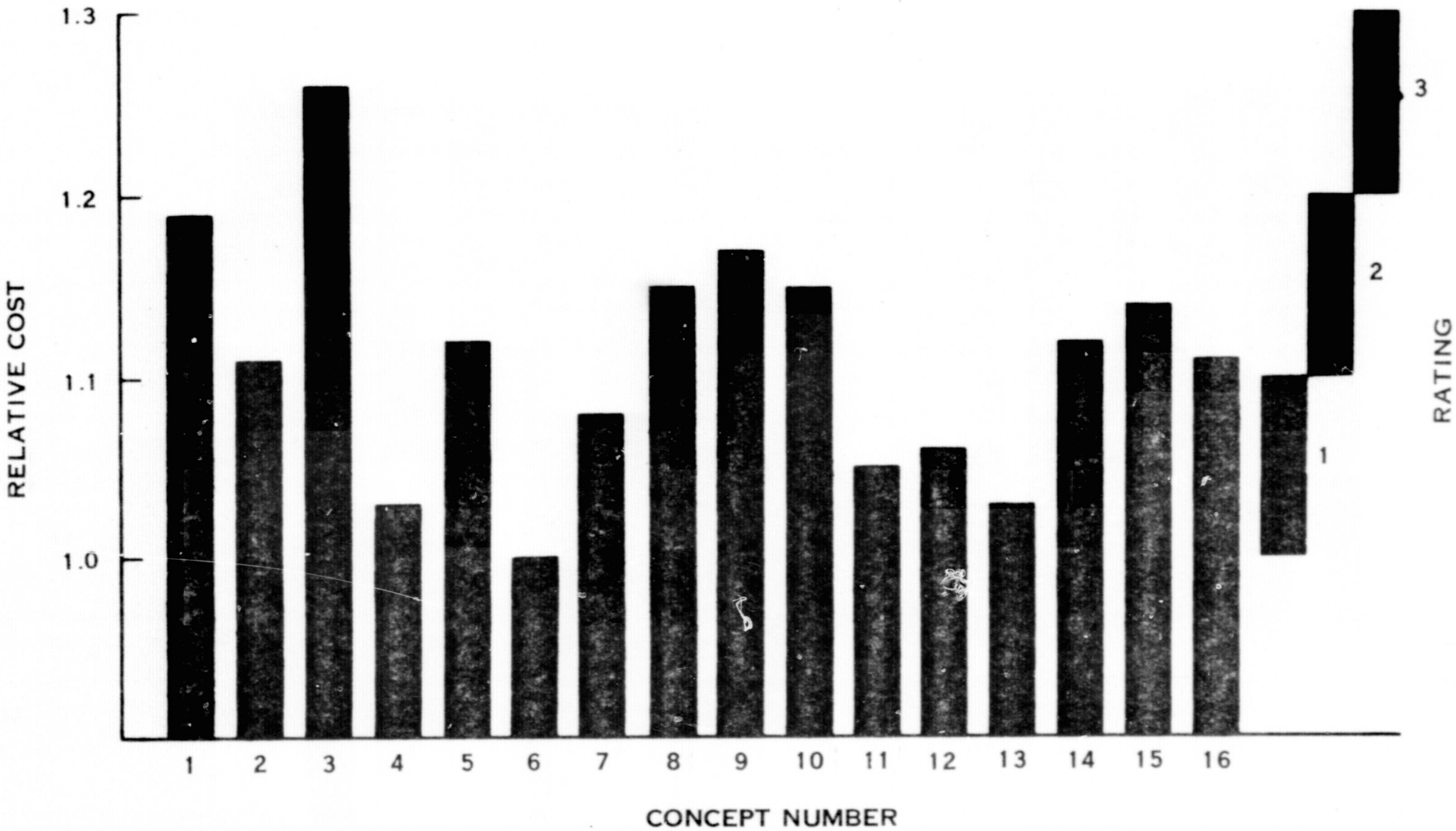

FIGURE 4—2—29 RELATIVE COST RATING

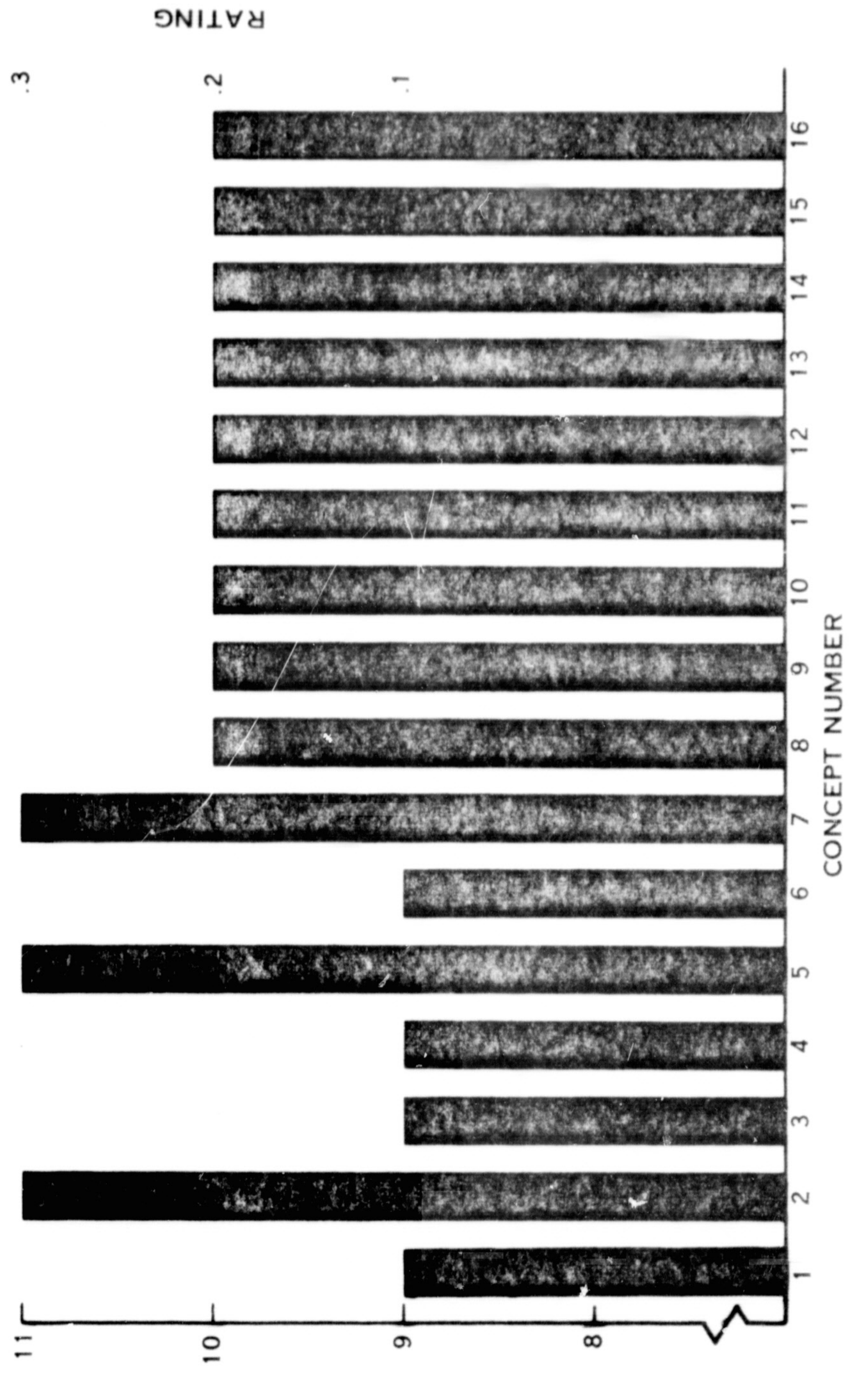

FIGURE 4-2-30 OPERABILITY RATING SUMMARY

TABLE 4-2-2
COMPLEXITY EVALUATION

Concept	Components Considered	Component Rating	System Rating
1	Motor, Electronics, Rotary Separator	4	2
2	Wick, 3 Way Valve	2	1
3	Motor, Electronics, Rotary Separator	4	2
4	Rotary Separator	1	1
5	Wick, 3 Way Valve	2	1
6	Rotary Separator	1	1
7	Wick, 3 Way Valve	2	1
8	H_2O Reg, O_2 Reg, Wick, 3 Way Valve	5	3
9	H_2O Reg. O_2 Reg, Wick, 3 Way Valve	5	3
10	H_2O Reg, O_2 Reg, Wick, 3 Way Valve	5	3
11	H_2O Reg, Wick, 3 Way Valve	3	2
12	H_2O Reg, Wick, 3 Way Valve	3	2
13	H_2O Reg, Wick, 3 Way Valve	3	2
14	O_2 Reg, Controller, Wick, 3 Way Valve, Nozzle/Solenoid	7	4
15	O_2 Reg, Controller, Wick, 3 Way Valve, Nozzle/Solenoid	7	4
16	O_2 Reg, Controller, Wick, 3 Way Valve, Nozzle/Solenoid	7	4

4.2.7 (Continued)

Component Rating	System Rating
1-2	1
3-4	2
5-6	3
7-8	4

The reliability evaluation consisted of an assessment of the critical failure modes affecting crew safety. Concepts 1, 3, 4, and 6 were rated first because they have no critical failure modes. Concepts 2, 5, 7, and 11 through 16 were rated second because the potential exists for a primary O_2 ventilation loop leak to vacuum through the elbow wick separator bladder or valve even though an orifice limits the leakage rate. Concepts 8, 9, and 10 were given the lowest reliability rating because the potential exists for over pressurizing the WMS, the HRS, and the primary O_2 ventilation loop from the high pressure regulators failing open.

A relative rating factor for each evaluation criteria was established for each concept. When these ratings were summarized and totaled (Table 4-2-3), it was determined that two concepts had the best ratings in each category; however, one of the two systems was lighter and smaller than the other. This concept consisted of a sublimator heat rejection subsystem, a bubble expansion tank water management subsystem, and a slurper/rotary separator humidity control subsystem (Figure 4-2-31). Thus, this was the selected concept.

4.2.8 Liquid Loop Gas Separator

Subsequent to selection of the Thermal Control System concept, means for removing free gas in the liquid circuit were evaluated. Hydrophilic screens were used successfully in both the Apollo and Skylab programs for separating free gas from water. This basic approach was also selected for the TCS. Several approaches for processing the separated gas were considered. They included: 1) storage in the separator, 2) venting overboard, and 3) venting to the gas circuit. Storage in the separator was rejected because of volume penalties, while venting overboard was rejected because of hardware complexity and violation of non-venting requirements. Two means of venting to the gas circuit were evaluated. They were: venting through a hydrophobic device and venting through the rotary water separator. Venting of the separated gas to the vent loop through a hydrophobic device was rejected because breakthrough of the hydrophobic device could result in rapid flooding of the vent circuit which represents an unacceptable hazard to the crewman. Failure of the concept using

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TABLE 4-2-3
TCS EVALUATION SUMMARY

				Rating			
Concept No.	Weight	Volume	Cost	Operability	Complexity	Reliability	Total
1	2	1	2	.1	2	1	8.1
2	3	3	2	.3	1	2	11.3
3	2	1	3	.1	2	1	9.1
4	1	1	1	.1	1	1	5.1
5	3	3	2	.3	1	2	11.3
6	1	1	1	.1	1	1	5.1
7	2	3	1	.3	1	2	9.1
8	3	2	2	.2	3	3	13.2
9	3	2	2	.2	3	3	13.2
10	3	2	2	.2	3	3	13.2
11	3	2	1	.2	2	2	10.2
12	3	2	1	.2	2	2	10.2
13	2	2	1	.2	2	2	9.2
14	3	4	2	.2	4	2	15.2
15	3	4	2	.2	4	2	15.2
16	3	4	2	.2	4	2	15.2

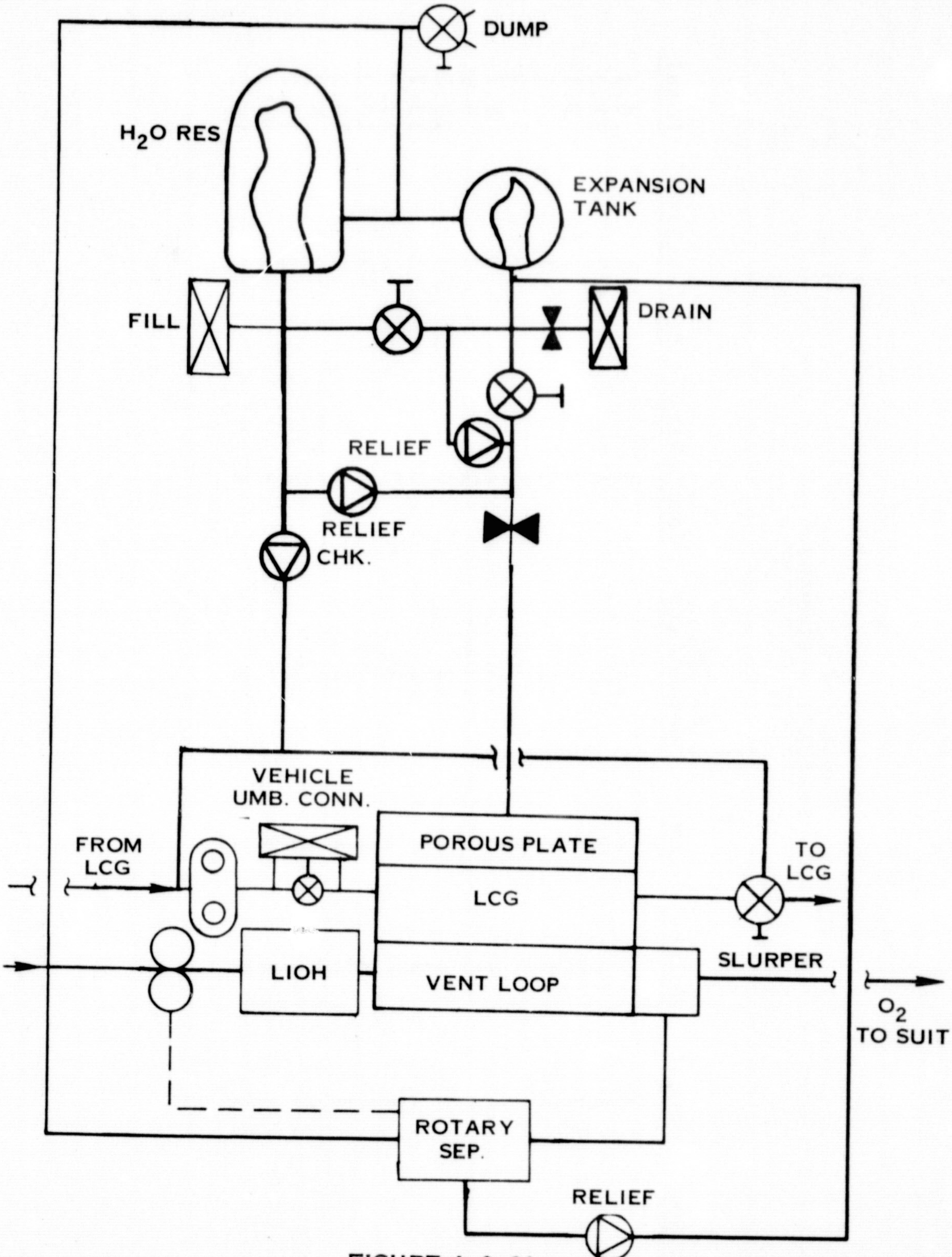

FIGURE 4–2–31

SELECTED TCS CONCEPT

4.2.8 (Continued)

the rotary separator (Figure 4-2-32) did not represent a safety hazard because water flow from the gas separator is controlled by several orifices. Should this device fail, there would be a gradual, detectable build up of water in the vent circuit allowing the crewman time to take the necessary corrective action.

4.3 Subsystem and System Design

This section provides a summary of the subsystem and system design details which are presented in more detail in the Phase 1 report.

4.3.1 Heat Rejection Subsystem Feasibility Test and Design Details

In support of the HRS design, a feasibility test program was conducted to obtain data for various porous plate materials. Figure 4-3-1 shows the test fixture utilized for these tests. With this device, the porous plate/heat exchanger interface was simulated while the thermal load was controlled by the two heaters in contact with the housing.

Testing consisted of: 1) steady state calibration during which the average housing temperature was obtained at various heat loads, and 2) hot start up performance during which the feed water flow was initiated after the entire test unit was stabilized at 38°C (100°F) to 40.4°C (105°F). The hot start test simulated the worst case heat soak in the vehicle and assumed no umbilical cooling of the system or crewman prior to start up.

Various plate materials were tested including sintered stainless steel, sintered teflon, sintered nickel, and calendered multilayer stainless steel screens. The calendered multi-layer stainless steel screen plate was found to be the most suitable for the HRS application. Figure 4-3-2 is a plot of average housing temperature versus heat load for the calendered stainless steel screen plate.

Figure 4-3-2 also shows the design point used in sizing the TCS sublimator. The unit was sized to reject a maximum load of 909 watts (3,100 Btu/hr) and a minimum load of 70 watts (240 Btu/hr) which were established as shown in Table 4-3-1.

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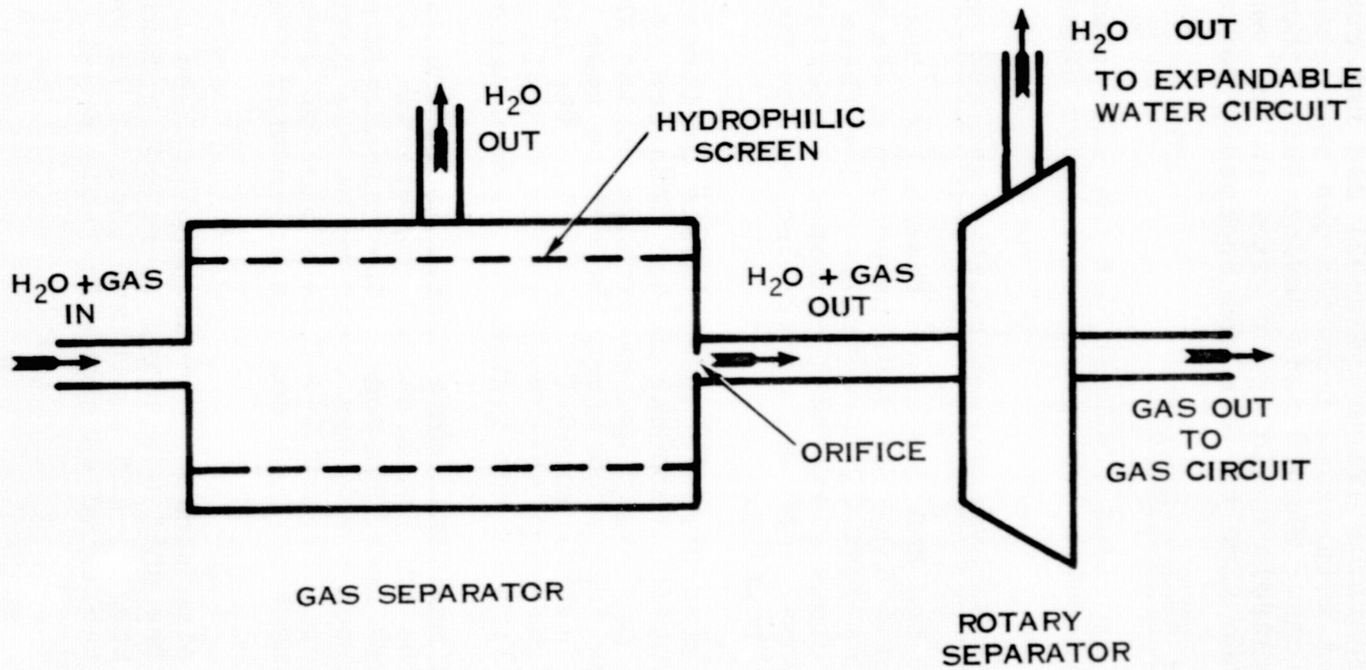

FIGURE 4-2-32
LIQUID LOOP GAS SEPARATION CONCEPT

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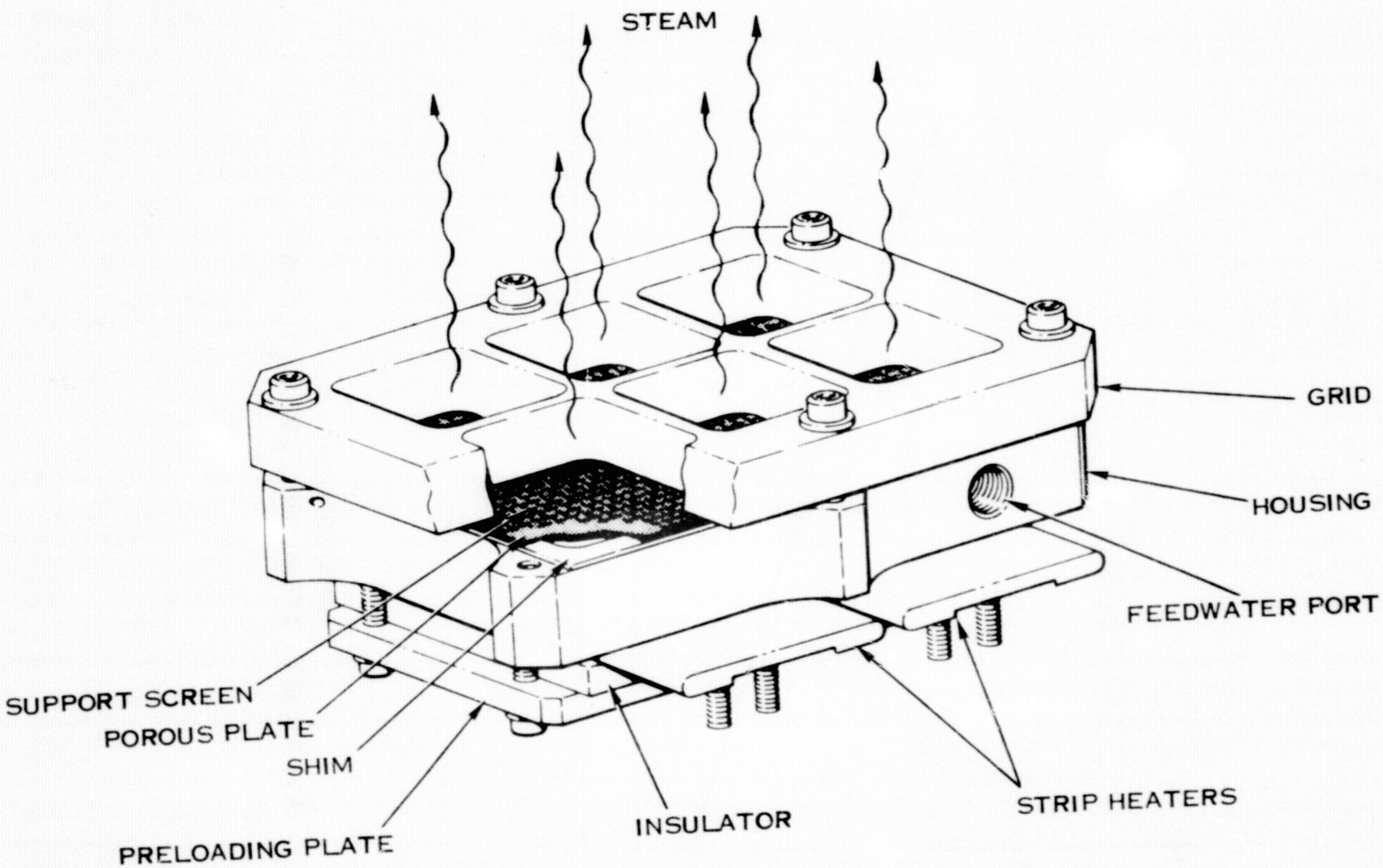

FIGURE 4-3-1
FEASIBILITY WATER SUBLIMATOR

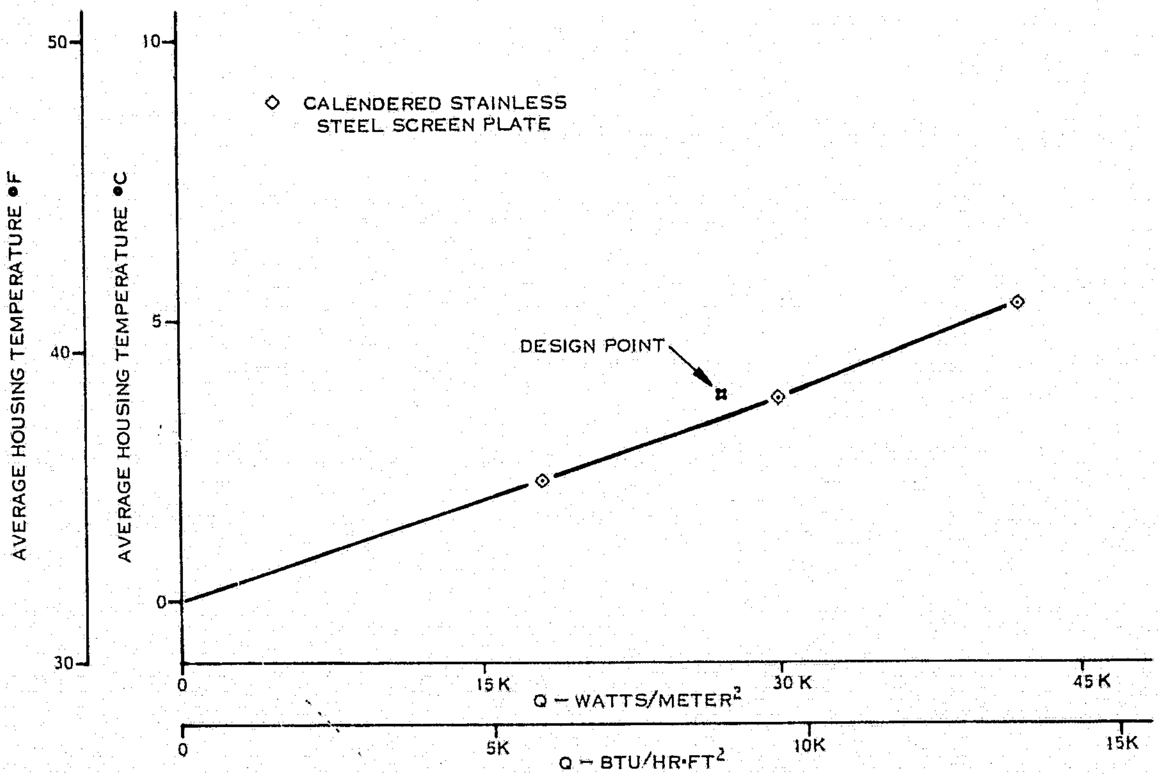

FIGURE 4—3—2
AVERAGE TEMPERATURE VS HEAT LOAD

4.3.1 (Continued)

TABLE 4-3-1
SUBLIMATOR HEAT LOAD

Constituent	Minimum Load Watts	Minimum Load Btu/Hr	Maximum Load Watts	Maximum Load Btu/Hr
Metabolic Load	117	400	587	+2,000
LiOH Load	0	+0	162	+560
Heat Leak	-117	-400	90	+300
Equipment Load	70	240	70	240
Total	70	240	909	3,100

During this program, two sublimators were designed, fabricated, and tested. The second of the two units was a refinement to the basic configuration based on fabrication and test of the first sublimator.

Figure 4-3-3 is an isometric view of the initial sublimator (SVSK 87220) showing the overall size and basic configuration. The major elements are the support grid, heat exchanger assembly, porous plate, and wire mesh spacer. The support grid and heat exchanger assembly are made of aluminum to minimize the sublimator weight and volume.

Figure 4-3-4 is a section through the vent loop headers and shows the relative location of the vent loop inlet and exhaust headers, the slurper header and outlet duct, the heat exchanger core, and the support grid.

The heat exchanger core, which is comprised of the LCG loop end sheet, LCG loop fins, housing, vent loop fins, and the vent loop end sheet is a fluxless brazed assembly to which the various headers are welded. After the heat exchanger is brazed and welded, the upper surface is machined flat, the feed water distribution slots and the 'O' seal groove are added, and the assembly is anodized for corrosion protection. The feed water gap is established by placing a shim between the heat exchanger housing and the porous plate. The support grid is used to minimize the deflection of the porous plate, and the stainless steel screen is used to minimize the back pressure in the area of the grid to prevent breakthrough. The design of the unit permits easy porous plate removal should it require field replacement or refurbishment.

In operation, the moist vent loop gas enters the unit at the inlet header, passes through the vent loop core, and exits at the vent loop exhaust heater. As the gas passes over the vent loop

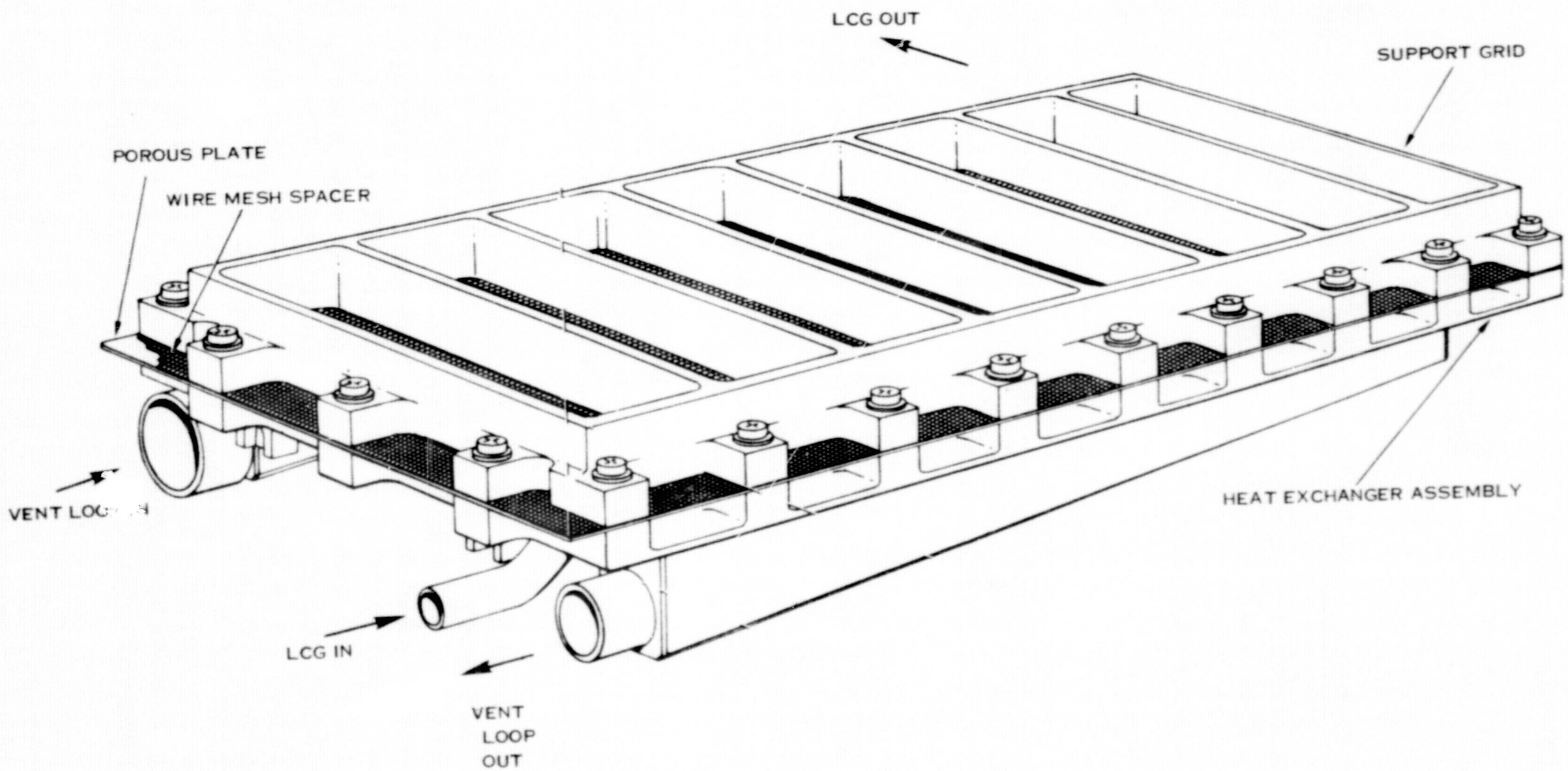

FIGURE 4—3—3

SUBLIMATOR

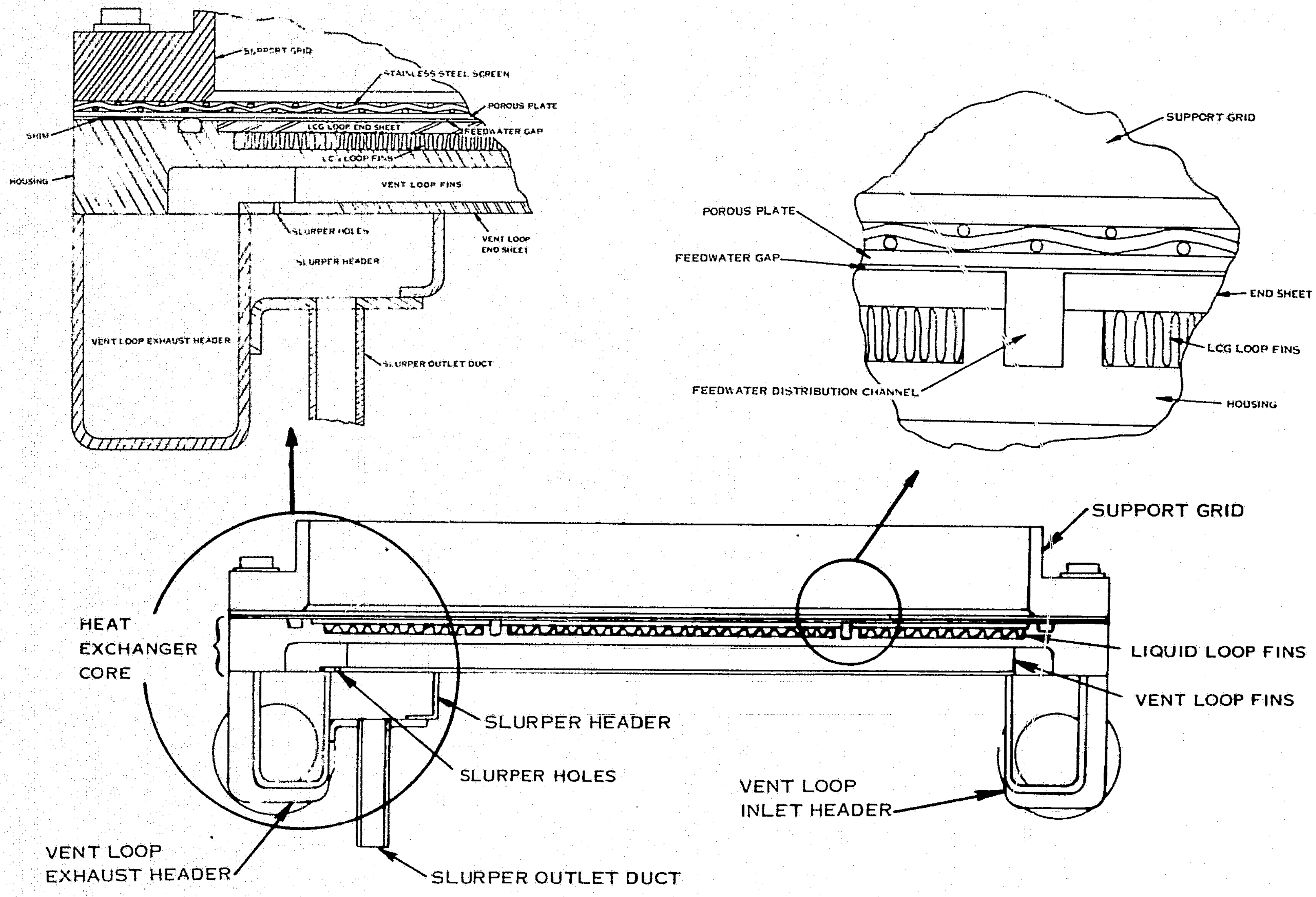

FIGURE 4–3–4
SUBLIMATOR CROSS SECTION THROUGH VENT LOOP HEADERS

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4.3.1 (Continued)

fins, it is cooled by heat transfer to the LCG side of the heat exchanger resulting in condensation of water on the fins. This water and a small amount of the inlet gas is drawn from the vent loop to the slurper header through the slurper holes. From the slurper header, the condensate is delivered to the second stage via the slurper outlet duct. The vent loop fins and inlet and exhaust headers are coated with a hydrophilic coating to assure that the condensed water will flow to the slurper holes.

Figure 4-3-5 is a cross section through the LCG loop headers showing the LCG inlet and outlet tubes, the feed water inlet, and the feed water distribution slot.

The blown up view depicts the feed water inlet. Feed water enters the unit through the feed water inlet tube and is supplied to the two feed water distribution slots through the channel.

Subsequent to the testing of the initial sublimator, the design of a second unit (SVSK 90302) was completed. The basic configuration of the second unit is the same as the initial unit, however, there are differences in the detail design in order to take advantage of the simplifications found possible and to correct problem areas detected during fabrication and test of the first unit. These items will be discussed in greater detail in the fabrication and test section of this report.

Figure 4-3-6 is an isometric view of the second generation unit, and Figure 4-3-7 is a cross section through the vent loop headers. The major differences between the two units are as follows:

- The 'O' ring seal and groove were eliminated and replaced by a gasket (A).

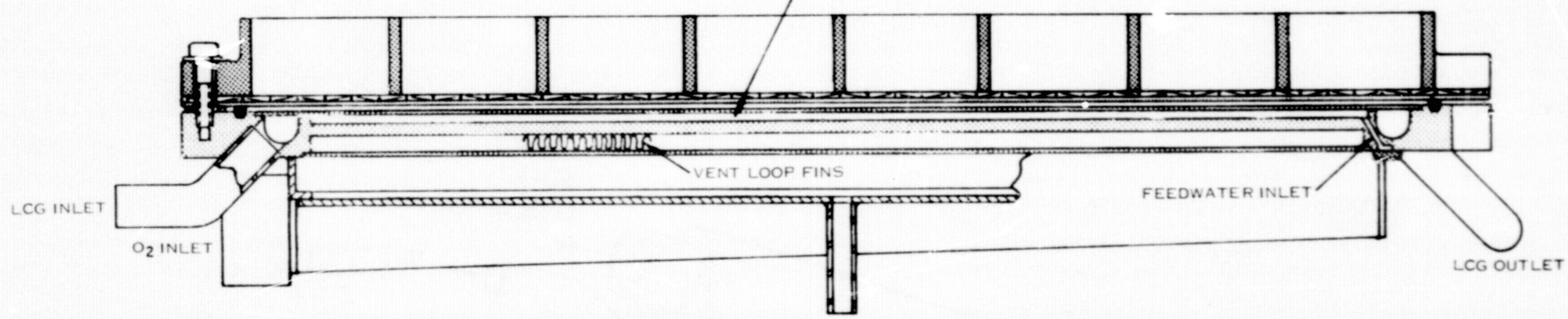
- The stainless steel screen between the porous plate and the support grid was eliminated (B).

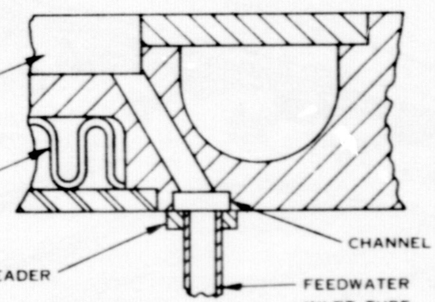
- The slurper holes were relocated and slurper header was made removable (C).

- The gas headers were reconfigured to minimize heat transfer between the headers and porous plate and to provide access to the vent circuit fins (D).

- The interface between liquid loop end sheet and heat exchanger housing was modified to facilitate weld repair in the event of leakage after braze (E).

Note: Letters refer to change locations on Figure 4-3-7.





FEEDWATER INLET DETAILS

FIGURE 4-3-5

SUBLIMATOR CROSS SECTION THROUGH LIQUID LOOP HEADERS

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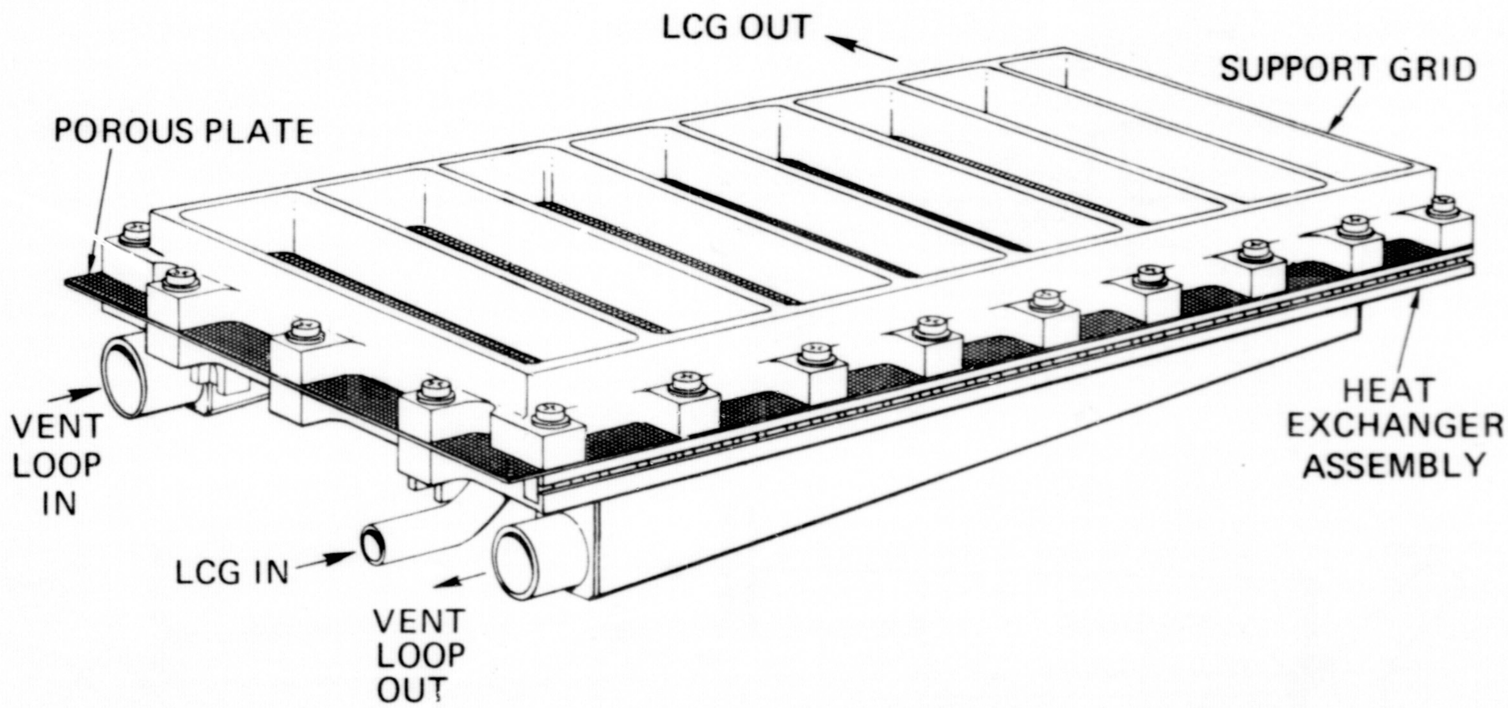
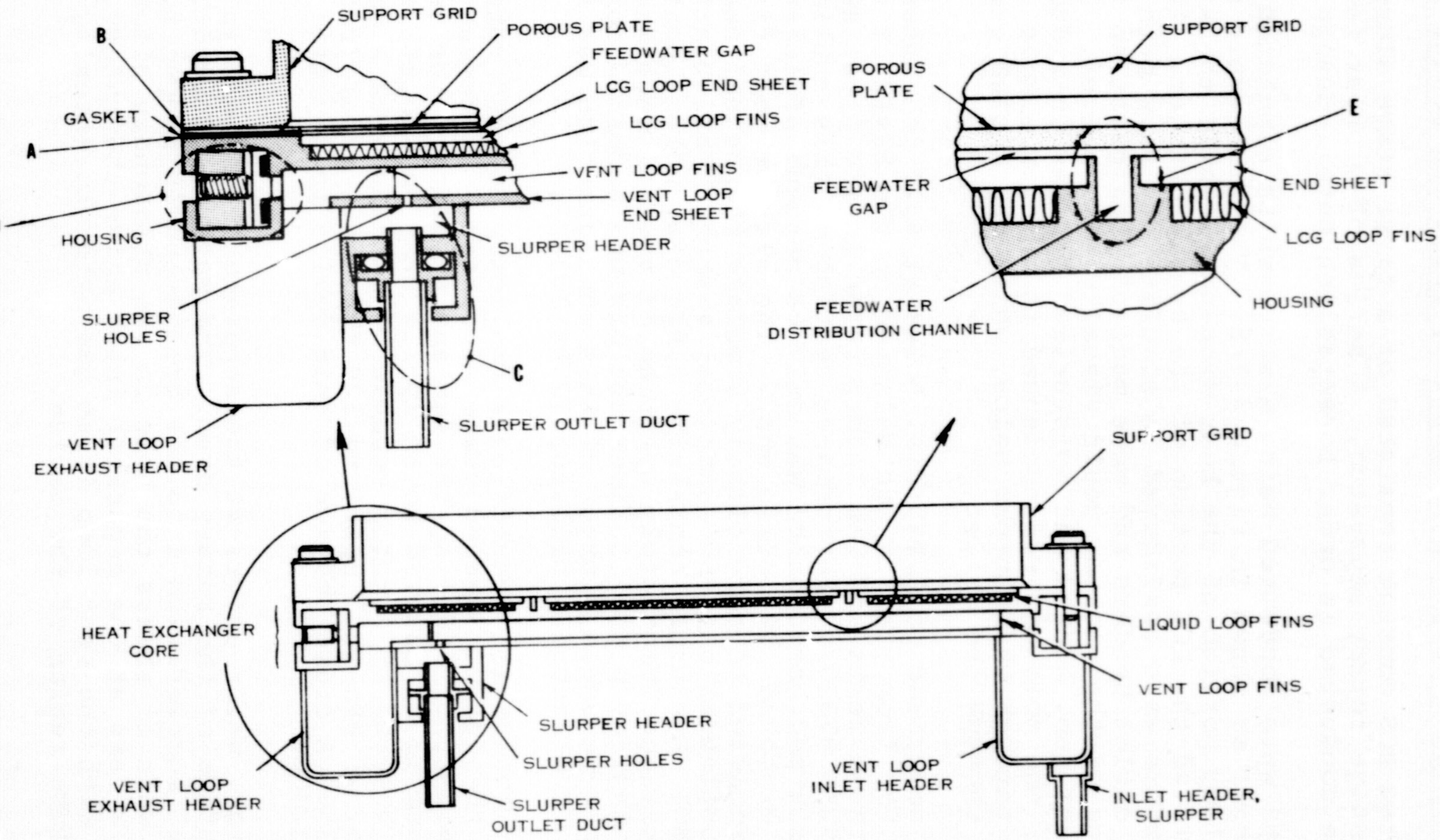


SECOND SUBLIMATOR

FIGURE 4-3-6



SECOND SUBLIMATOR
CROSS SECTION THROUGH VENT LOOP HEADERS

FIGURE 4-3-7

4.3.2 Humidity Control Subsystem Feasibility Tests and Design Details

The selected HCS concept consisted of a first stage slurper and a second stage rotary separator. A series of slurper feasibility tests were conducted in order to establish detail design data.

These tests were conducted using a setup which simulated the TCS heat exhanger as shown in Figure 4-3-8. The fin sample simulated the vent loop portion of the heat exchanger, while the water circuit simulated the LCG portion of the heat exchanger. The sides of the fixture were configured to simulate the flow path in the inlet and outlet headers and were made of plexiglass so that the performance of the slurper could visually be observed. In a typical test run, heated and moisturized gas was introduced at the inlet, the moisture was condensed in the fin sample and was withdrawn through the slurper holes, while the cooled gas was exhausted through the outlet.

A slurper comprised of 0.020 dia. holes at 0.25 in. intervals located 0.050 from the fin was selected on the basis of the results of these tests and was incorporated in the first sublimator (SVSK 87320). Performance testing of this sublimator revealed slurper performance was only 86 percent efficient versus an expected 100% efficiency. The slurper test fixture was then modified to more closely simulate the actual heat exchanger configuration, and additional slurper configurations were tested. A slurper containing 0.016 dia. holes located in each fin passage immediately upstream of the fin edge was found 100% efficient even at 1.5 times the maximum expected condensate generation rate and a slurper of this configuration was incorporated in the second sublimator (SVSK 90302).

The system evaluation identified a fan motor powered rotary separator as the optimum second stage separator. To demonstrate the feasibility of coupling the fan and separator, the separator was designed to be coupled to an Apollo PLSS fan volute and rotor and powered by a motor capable of running with a gas loop pressure of 26 KPa (3.7 psia) to 129 KPa (18.7 psia) (reference SVSK 87343). A cross section of this device is depicted in Figure 4-3-9.

In operation, water enters at the separator inlet and is slung to the surface of the rotary drum. The water is forced by centripital acceleration into the trough and is pumped from the separator when it enters the hole in the stationary pitot. The gas which enters at the separator inlet exits the rotary drum and mixes with the vent loop inlet gas prior to entering the fan rotary/volute region of the device.

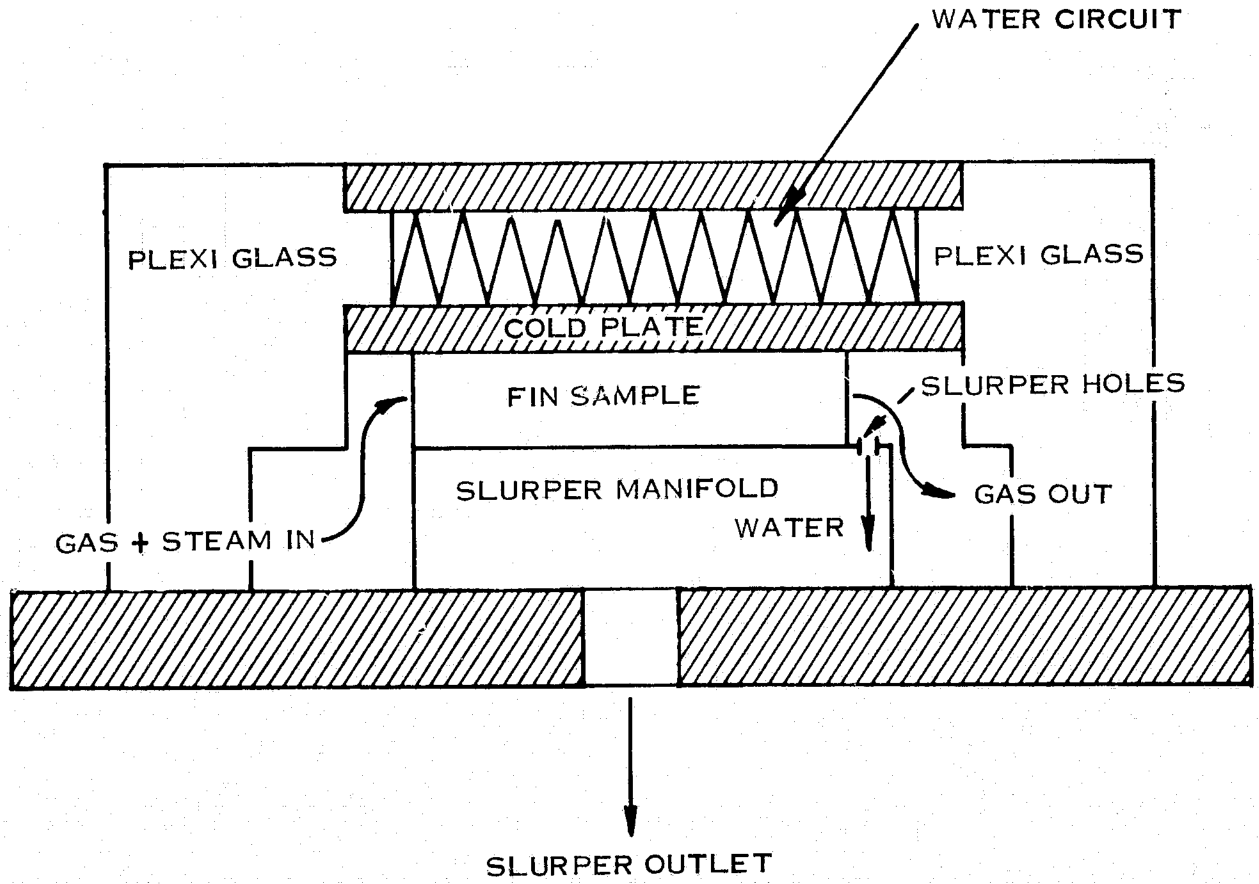


FIGURE 4-3-8

TCS SLURPER TEST FIXTURE AND SAMPLE

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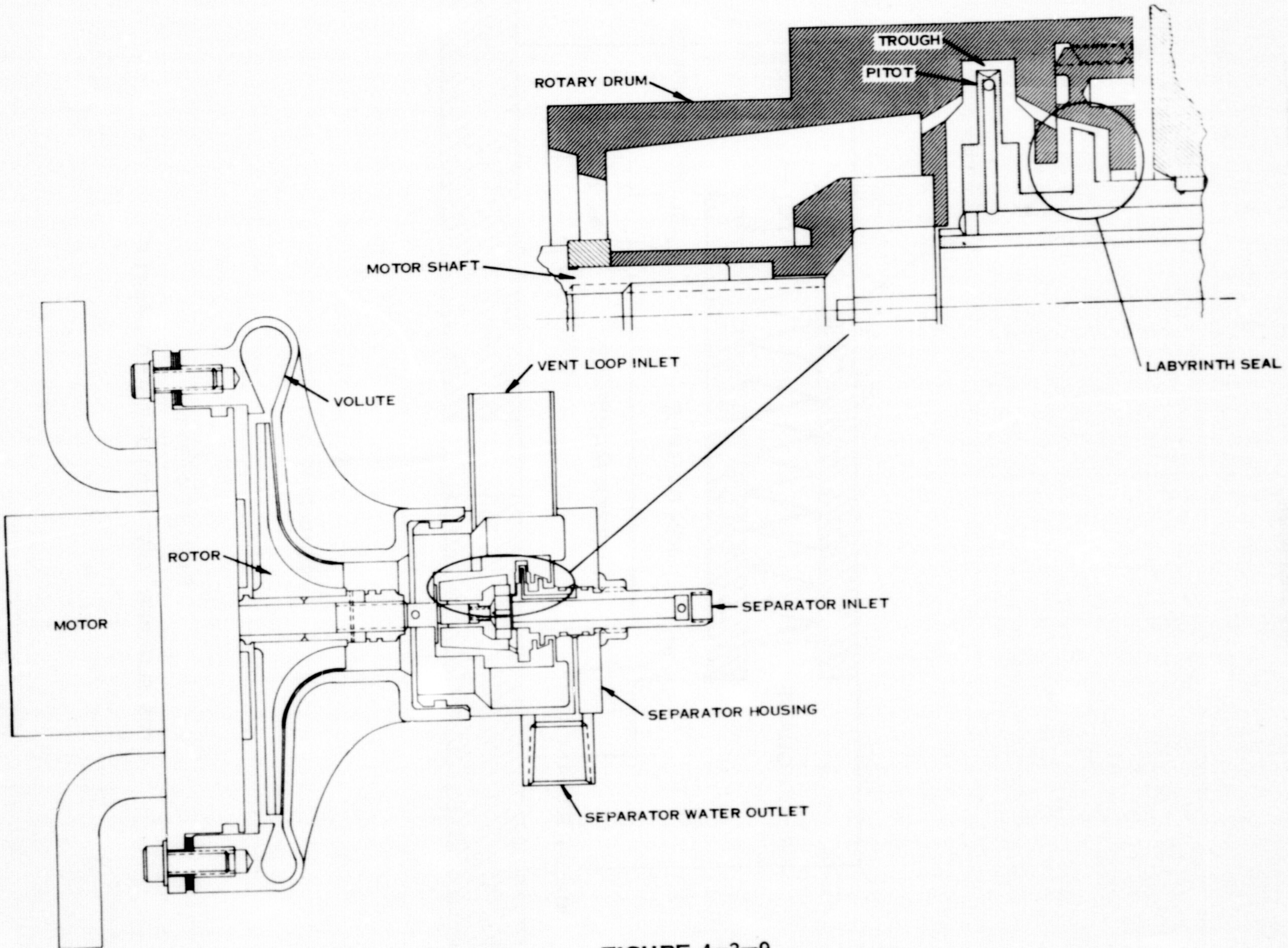


FIGURE 4—3—9
FAN / ROTARY SEPARATOR

4.3.3 Water Transport Subsystem Feasibility Test and Design Details

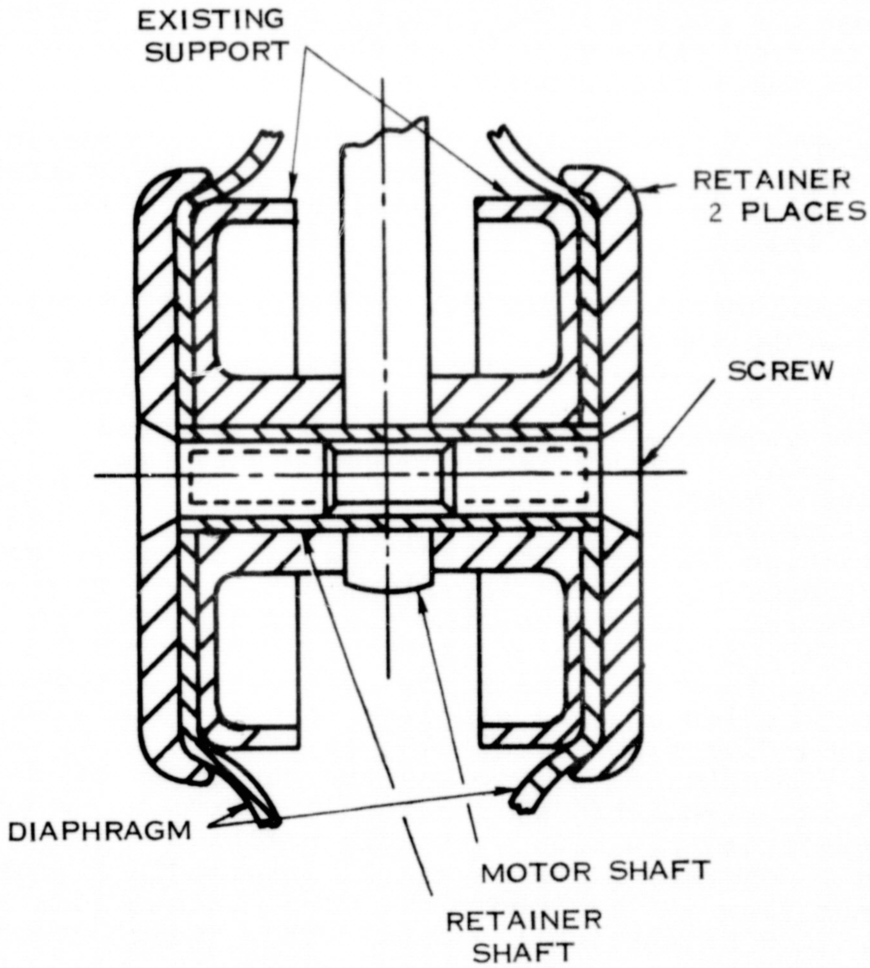
The selected WTS consists of a pump, temperature control valve (TCV), gas separator, and vehicle umbilical connector. The pump selected for use in the TCS was a GFE Apollo PLSS pump (SV713867), and a GFE Skylab water diverter valve was selected to simulate the function of the TCV designed during this program.

The WTS design activity included definition of charges that would improve the pump maintainability and detail design of a temperature control valve as well as the design of a gas separator and a vehicle umbilical connector.

The pump's maintainability was improved by redesigning the pump diaphragm retainer to make the retainer and diaphragm field replaceable. The redesigned retainer (SVSK 90341) is shown in Figure 4-3-10.

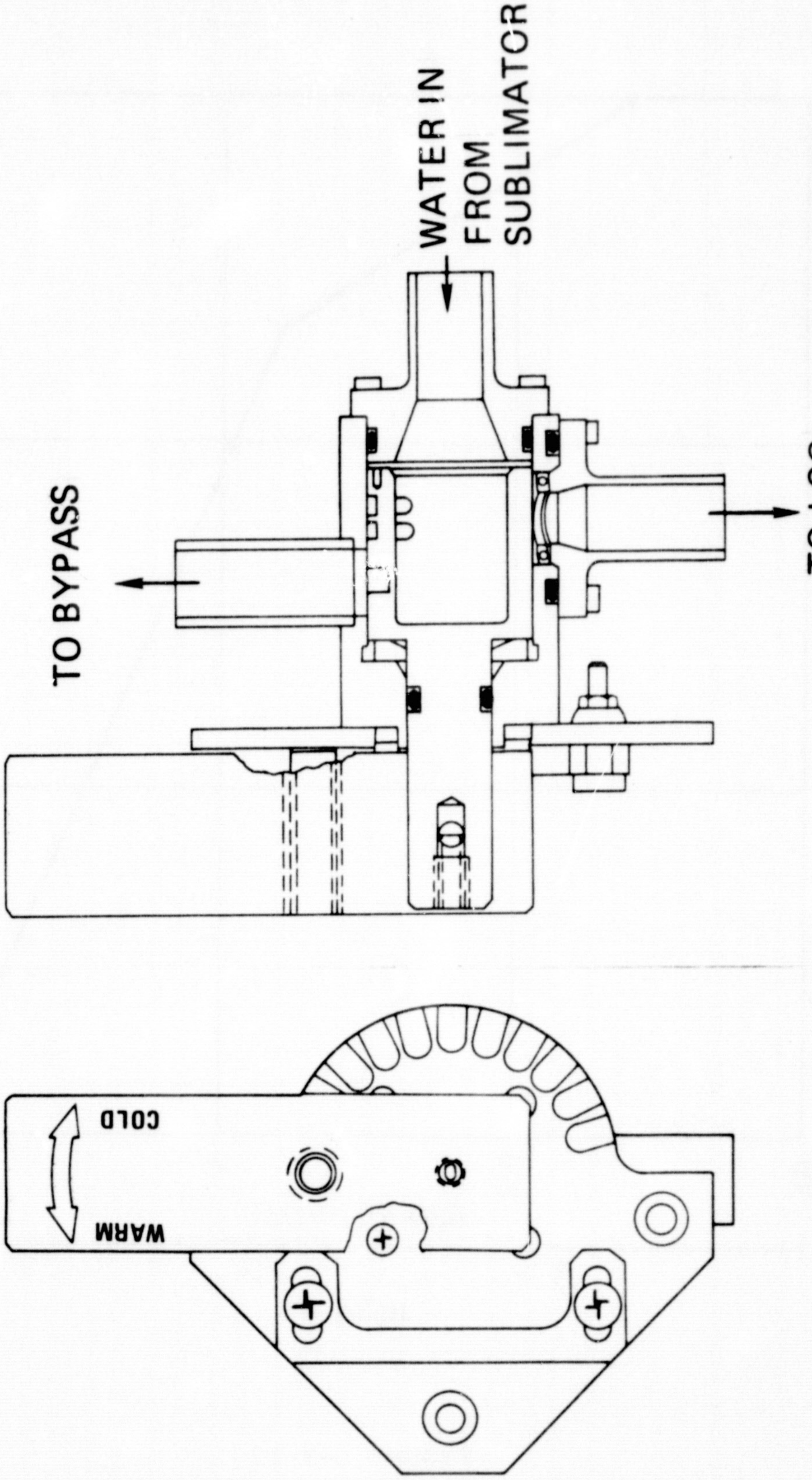
The requirements for the TCV included close control of the minimum flow to the LCG (1.36 $\pm$ .68 Kg/hr (3.0 $\pm$ 1.5 lb/hr)) and provision for at least 6 intermediate flows between minimum and maximum flow to the LCG. To meet these requirements, a spool valve utilizing variable depth grooves was selected. The variable depth grooves were selected because they are easily sealed, their effective area is easily controlled, and the minimum flow can be set after the valve is assembled by simply adjusting a stop, thus eliminating the need for indexing and matching parts. The use of the grooves to control the flow split makes it possible to select any desired flow between the minimum and maximum. Figure 4-3-11 contains a cross section of the TCV (SVSK 90350). Water entering the valve from the sublimator enters the 2 grooves in line with the LCG outlet and the single groove in line with the bypass. The amount of flow to each leg is controlled by the flow area available between the grooves and the edges of the outlet holes which is established by the handle position. Figure 4-3-12 shows the predicted LCG flow vs handle position. There are detents every 15 degrees so there are 11 intermediate positions between minimum flow and maximum flow. The minimum flow to the LCG is controlled by setting the handle stop during the check out test.

Figure 4-3-13 is a cross section of the gas separator (SVSK 90475). When water and free gas enter the unit, the majority of the water flows through the hydropholic screen to the pump inlet while a small amount of the water flows through the orifices to the rotary separator. The hydropholic screen traps the gas and prevents it from flowing to the pump. The pressure on the inside of the screen is higher than the pressure at the rotary separator so



Maintainable Pump Diaphram Assembly

Figure 4-3-10



Temperature Control Valve

Figure 4-3-11

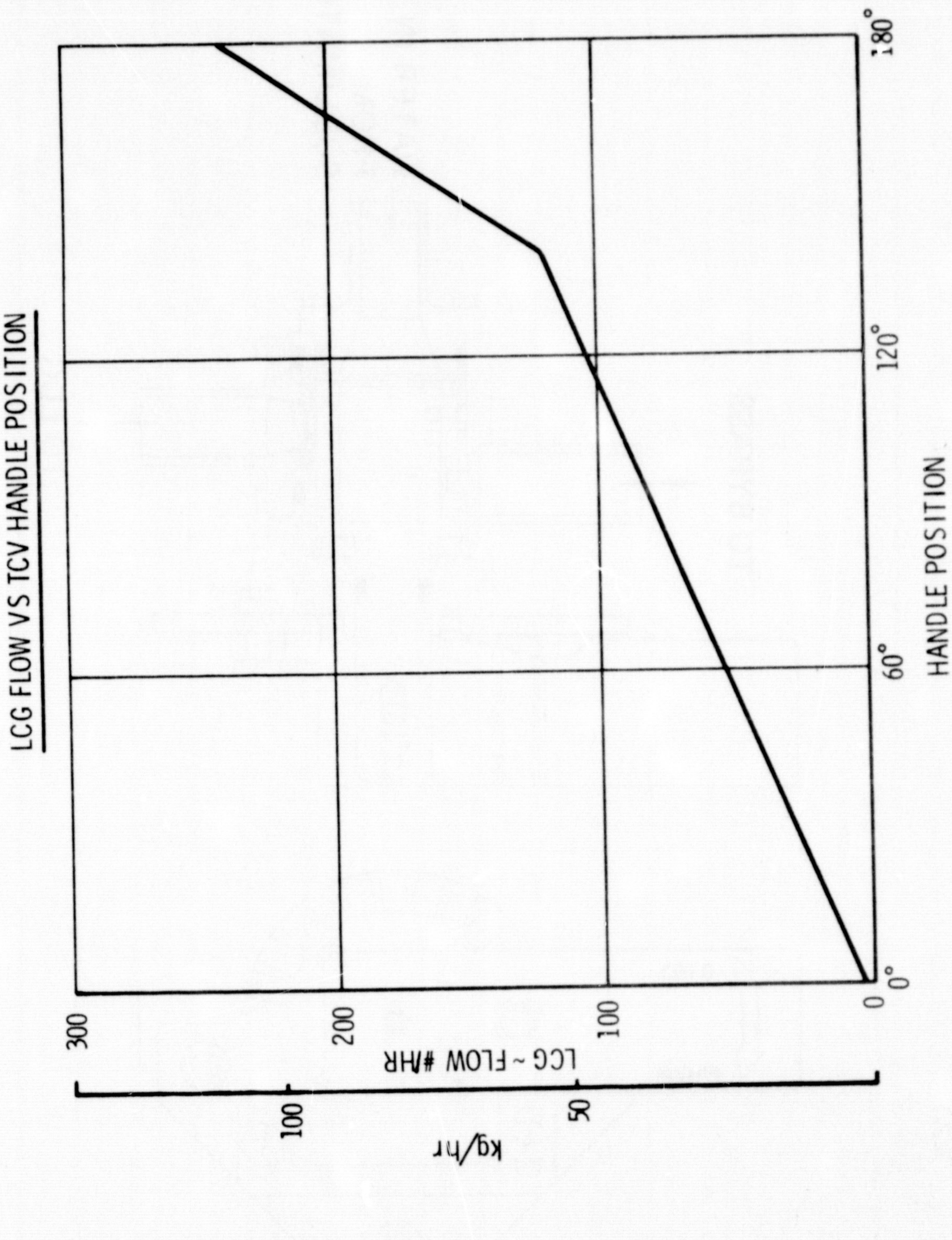
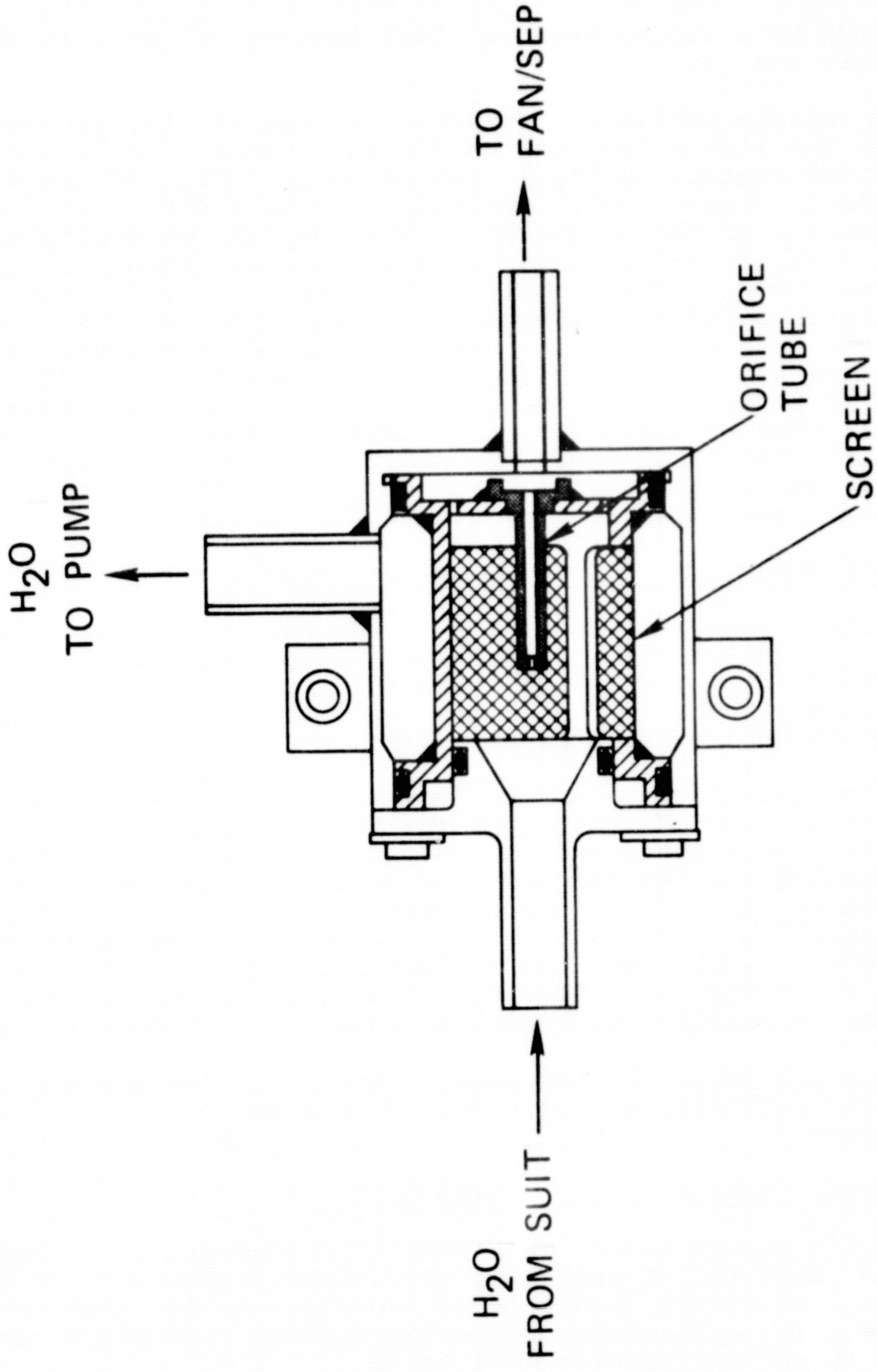

LCG FLOW VS TCV HANDLE POSITION
HANDLE POSITION
0°
60°
120°
180°
LCG ~ FLOW #/HR
0
100
200
300
kg/hr
50
100

FIGURE 4-3-12



Gas Separator
Figure 4-3-13

the gas flows from the screen, through the orifices to the rotary separator. The feasibility of this type of separator was confirmed by Hamilton Standard IR&D testing of the unit shown in Figure 4-3-14.

The vehicle umbilical connector, Figure 4-3-15, is used to connect the liquid loop of the TCS to a vehicle cooling system for thermal control during intra-vehicular operation and during non-venting extravehicular operation. Figure 4-3-16 is a functional schematic of the connector in the coupled and uncoupled modes while Figure 4-3-17 is a cross section of the connector in the coupled mode. When coupled, an integral shutoff feature in the backpack portion of the connector is closed diverting all water to and from the vehicle. When uncoupled, the integral shutoff feature is opened allowing water to flow directly from the inlet to the outlet of the connector, while at the same time, the flow ports that mate with the umbilical portion are shut off. The vehicle umbilical connector (SVSK 90196) utilizes Apollo multiple water connector details that were rearranged and modified to satisfy the operation requirements of the vehicle umbilical connector.

4.3.4 Water Management Subsystem Design Details

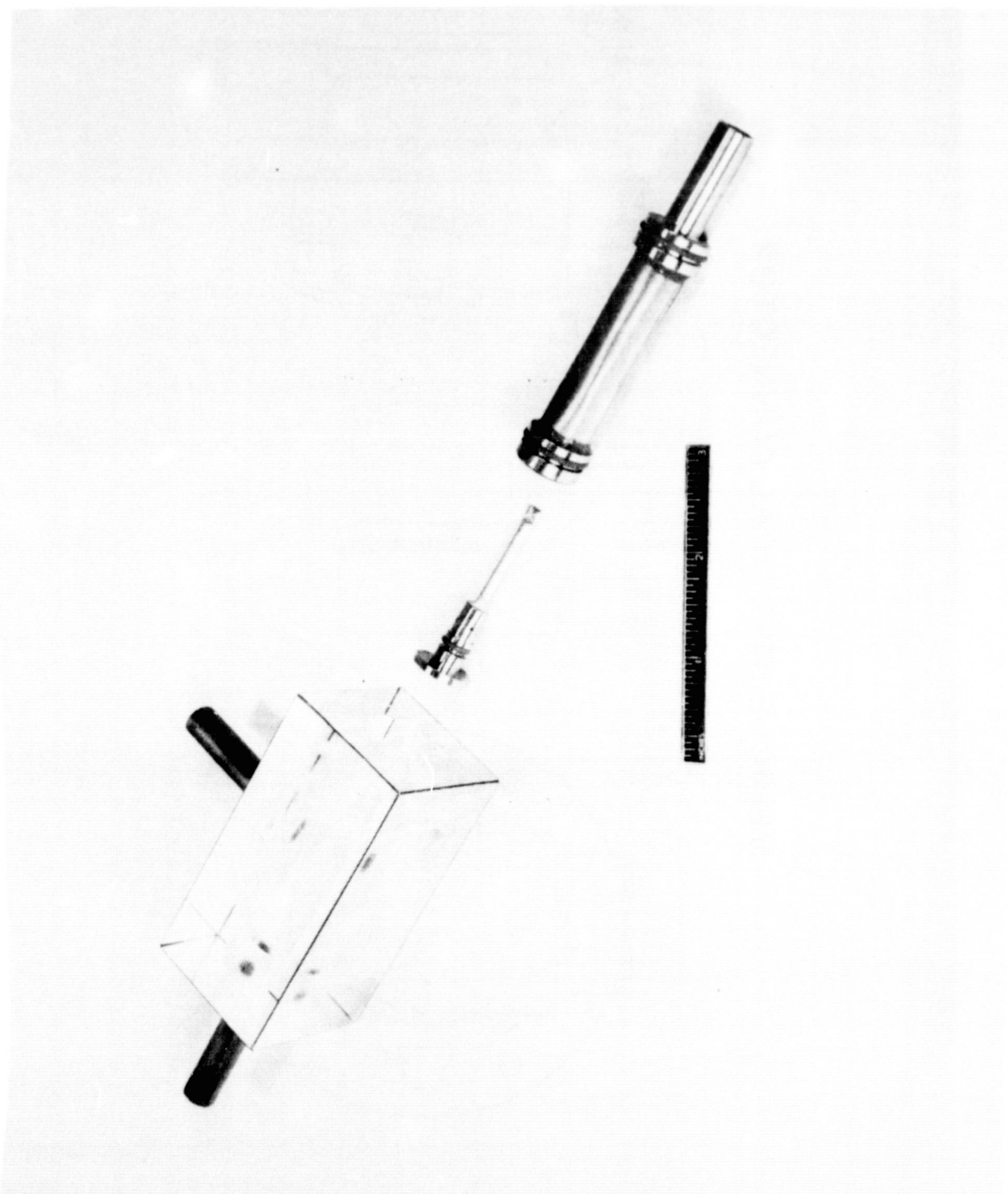
Figure 4-3-18 is a schematic of the WMS. It consists of commercial stainless steel shutoff and relief valves, an Apollo PLSS canister reservoir, fill and drain connector, check valve, and an auxiliary reservoir which was reworked to reduce the volume to that of the bubble expansion tank.

Figure 4-3-19 shows how the volume of Apollo PLSS auxiliary reservoir was reduced to that of the bubble expansion tank. The outer shell rework consisted of removing a segment of the tank wall and rewelding the two halves. The upper bladder restraint was changed as shown to simplify the clamping details and to eliminate the possibility of cutting the bladder with the assembly tools. The bladder rework consisted of removing a segment and then bonding the two halves with RTV 102. A portion of the segment removed from the bladder was bonded as shown to reinforce the joint.

Since all other WMS components were either commercial hardware or Apollo hardware, no additional detail design was conducted for the WMS.

4.3.5 Thermal Control System Design Details

The TCS design effort consisted of conducting a TCS instrumentation study and of packaging the four subsystems. The instrumentation study was conducted to identify the TCS instrumentation necessary to furnish caution and warning information for crew safety and performance monitoring.



FEASIBILITY GAS SEPARATOR

FIGURE 4-3-14

VEHICLE UMBILICAL CONNECTOR

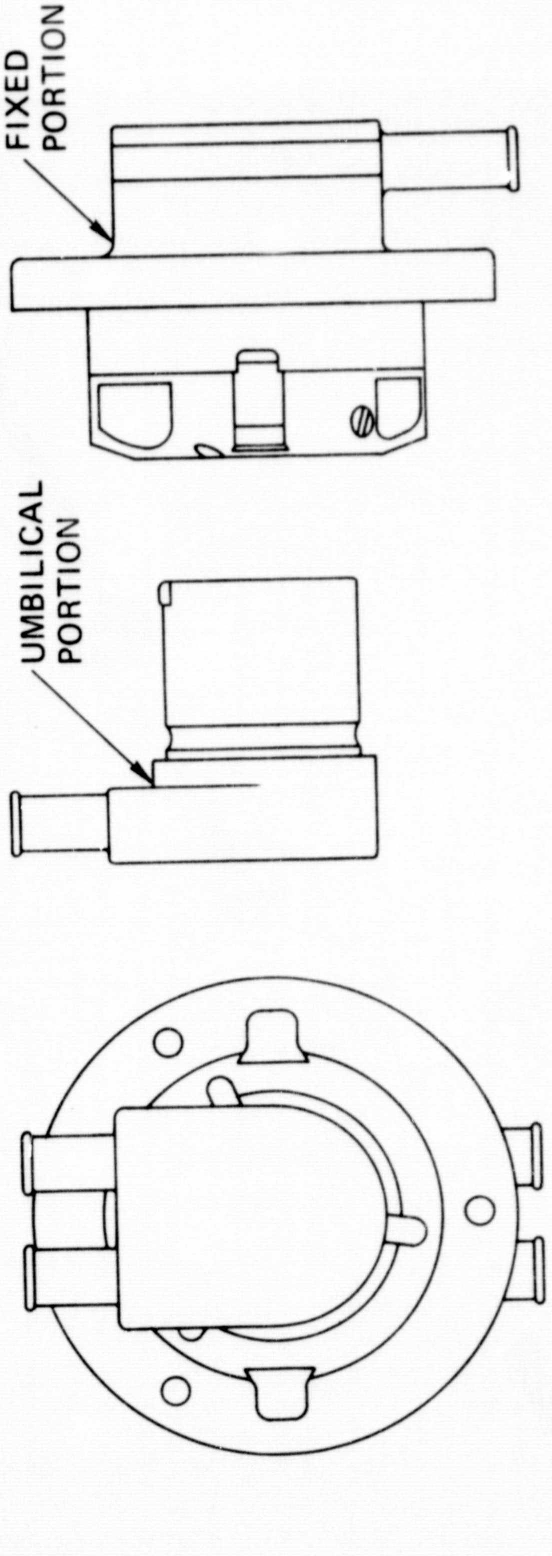
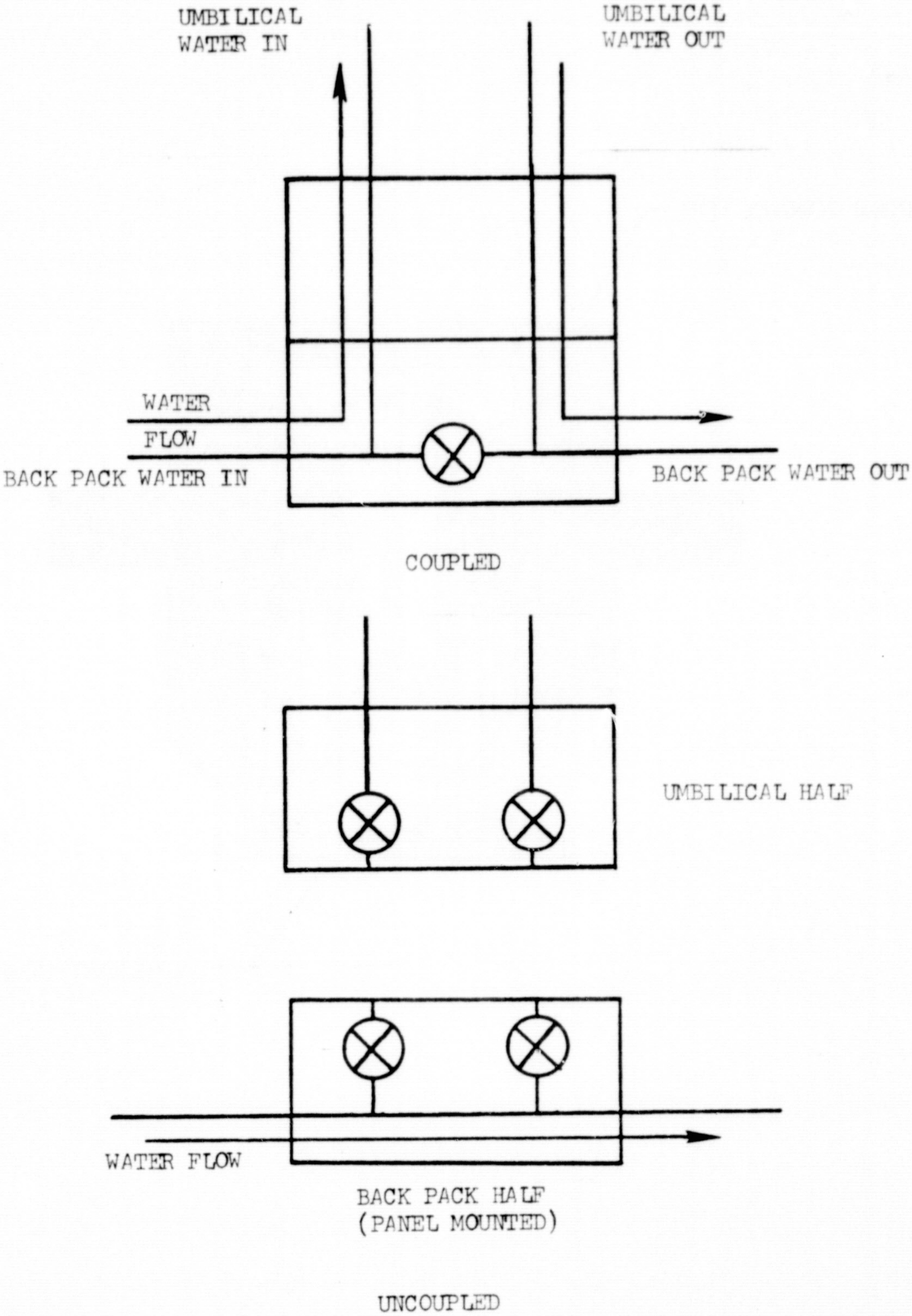
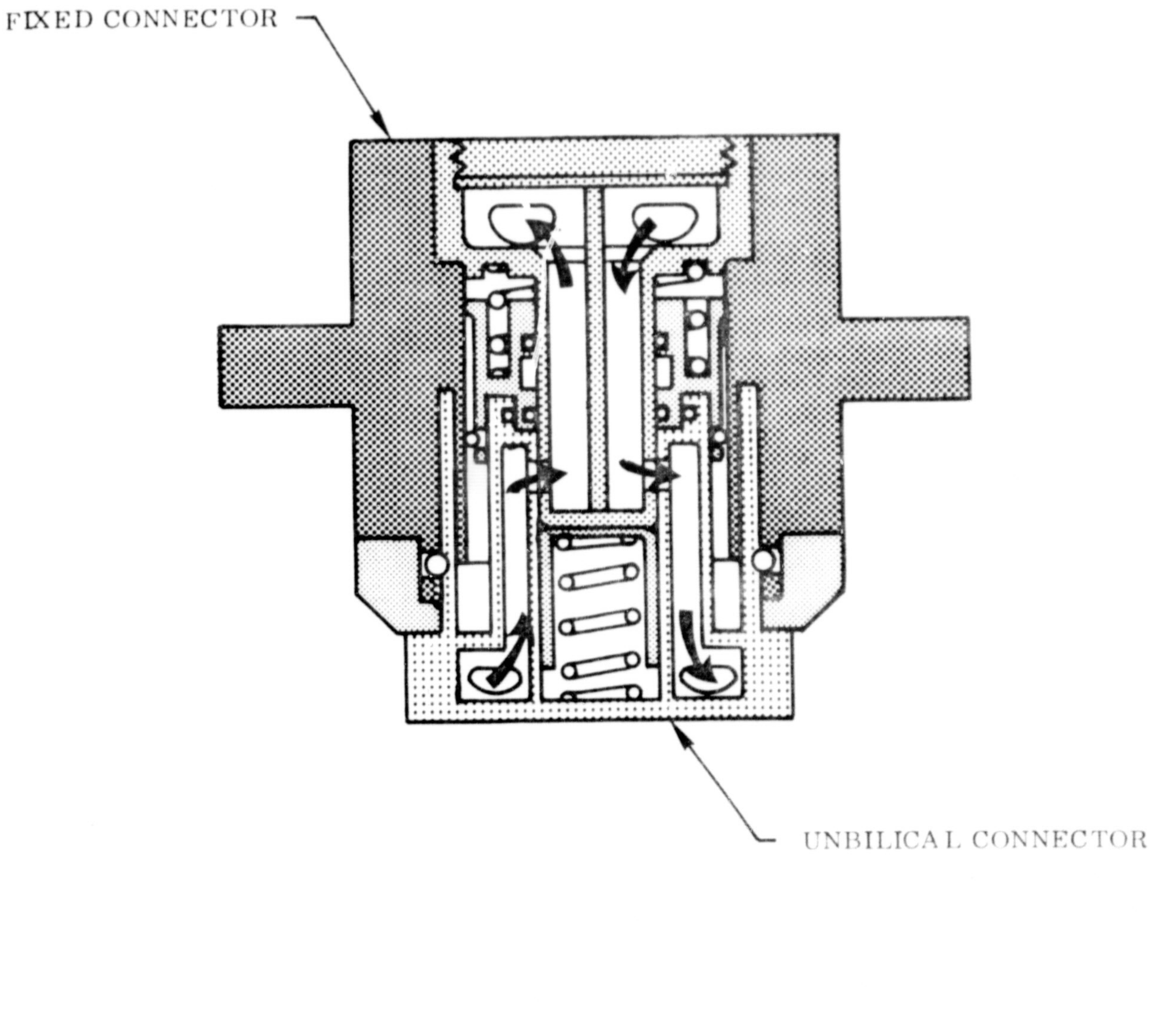


FIGURE 4-3-15



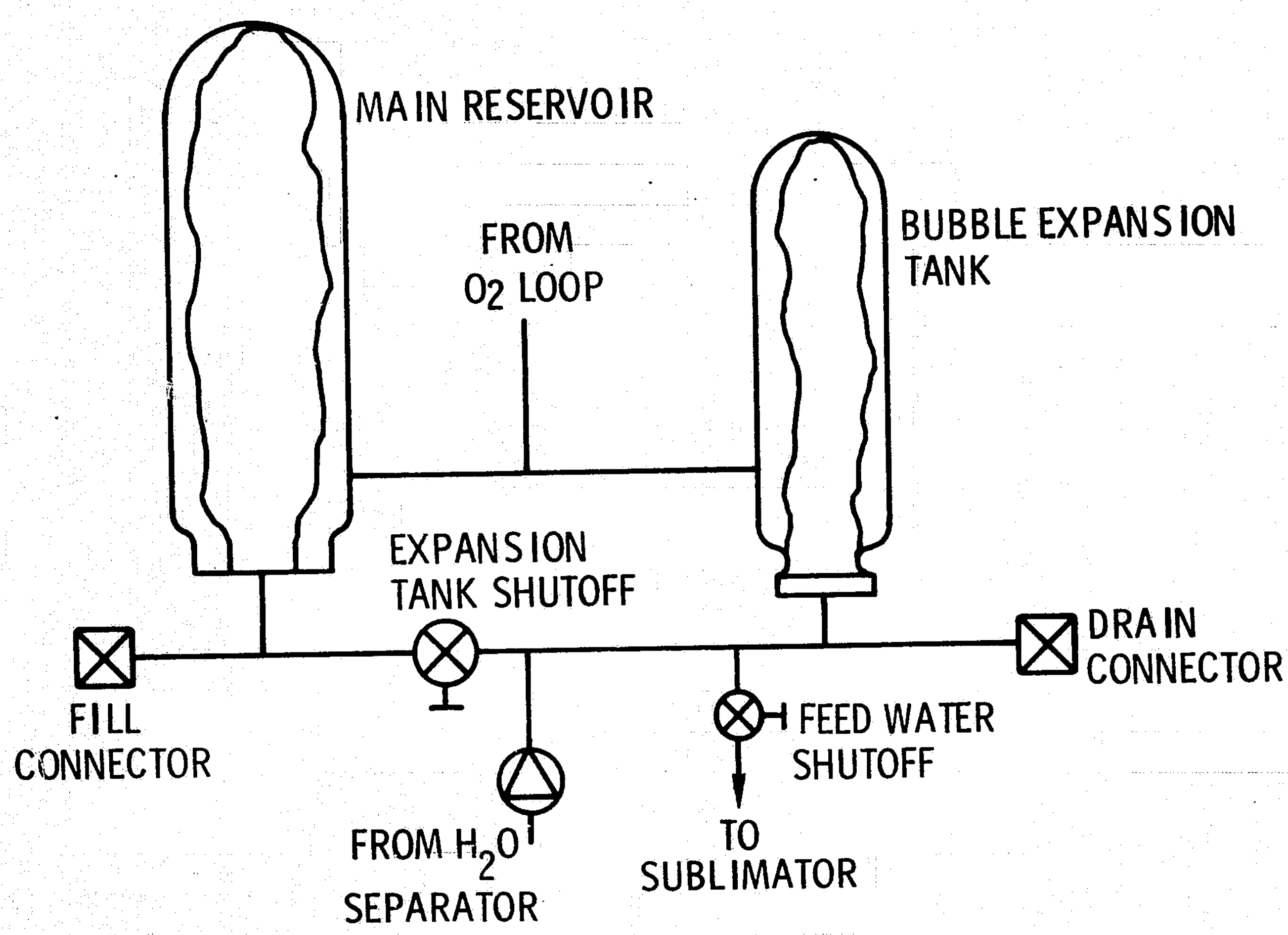
Vehicle Umbilical Connector Functional Schematic

Figure 4-3-16



VEHICLE UMBILICAL CONNECTOR
FUNCTIONAL CROSS SECTION

FIGURE 4-3-17



Water Management Subsystem
Figure 4-3-18

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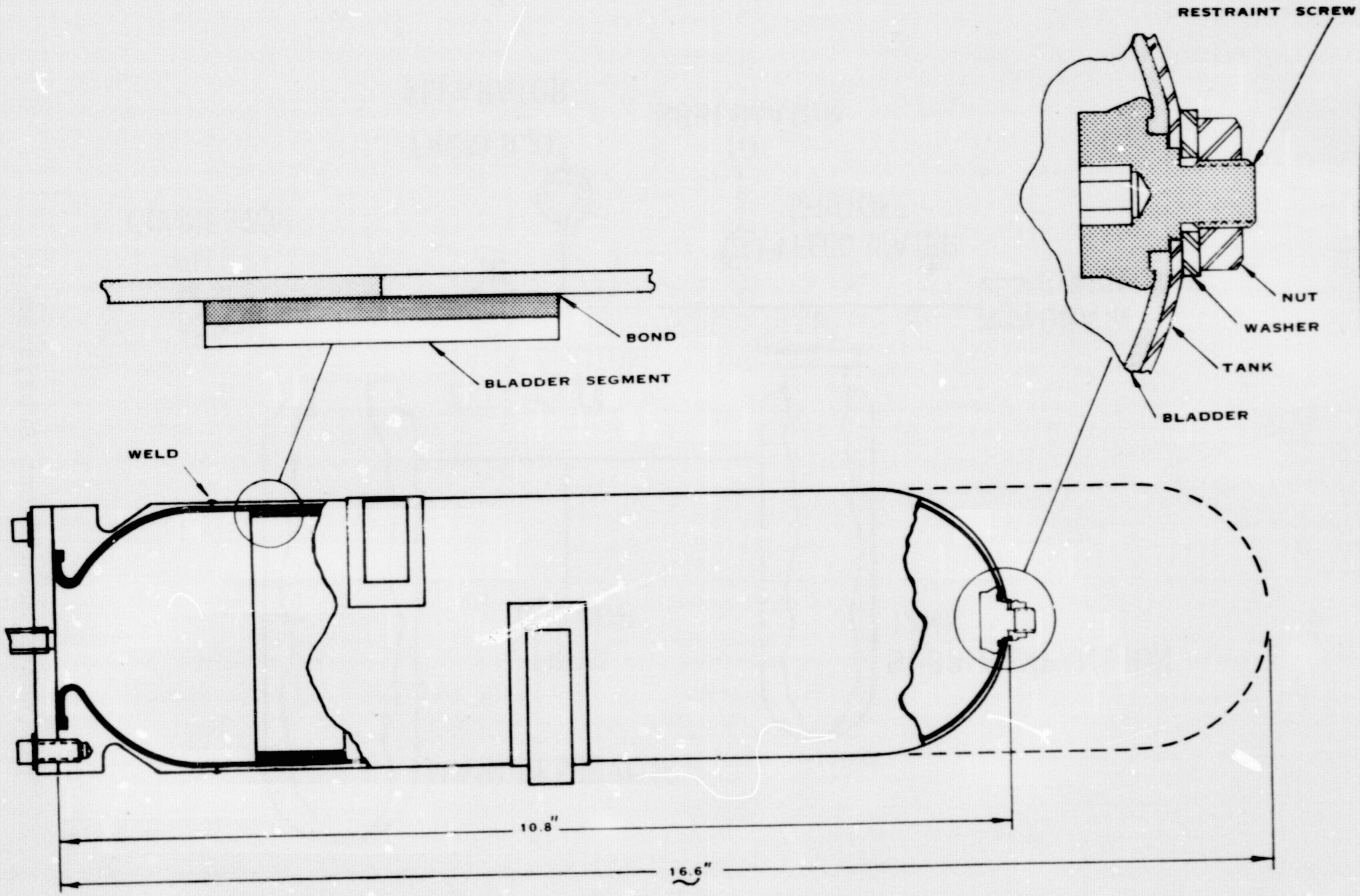


BUBBLE EXPANSION TANK

FIGURE 4-3-19

4.3.5 (Continued)

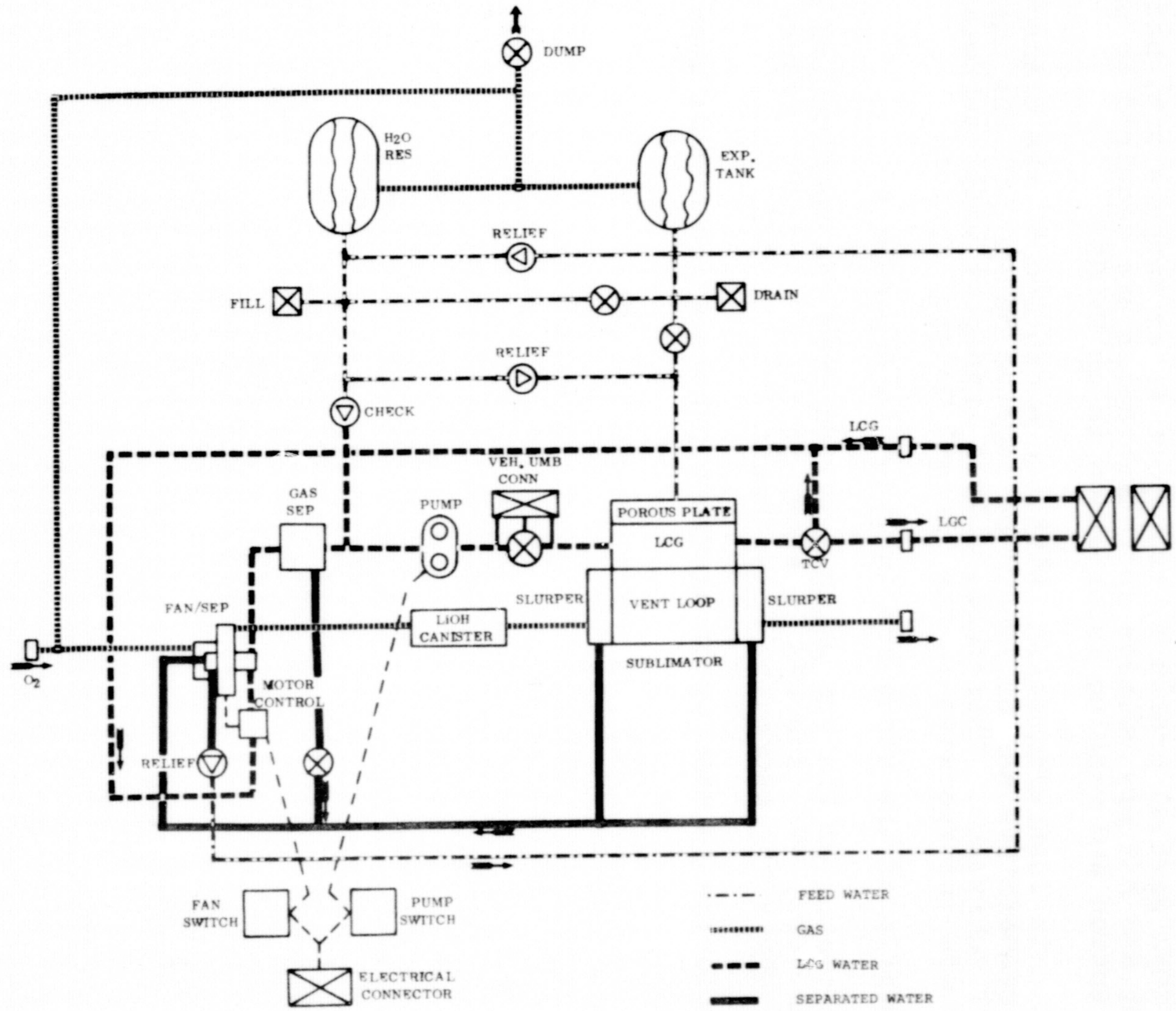
It was concluded that O_2 tank pressure, suit pressure, $O_2$2 vent flow, $CO_2$2 partial pressure, transport water temperature, battery current and battery voltage instrumentation are required to provide caution and warning information in an EVLSS.

All of this instrumentation, with the exception of the transport water temperature sensor, would be located outside of the thermal control subsystem. Therefore, only a transport water temperature sensor was incorporated in the Thermal Control System.

The details of the study are included in Appendix B.

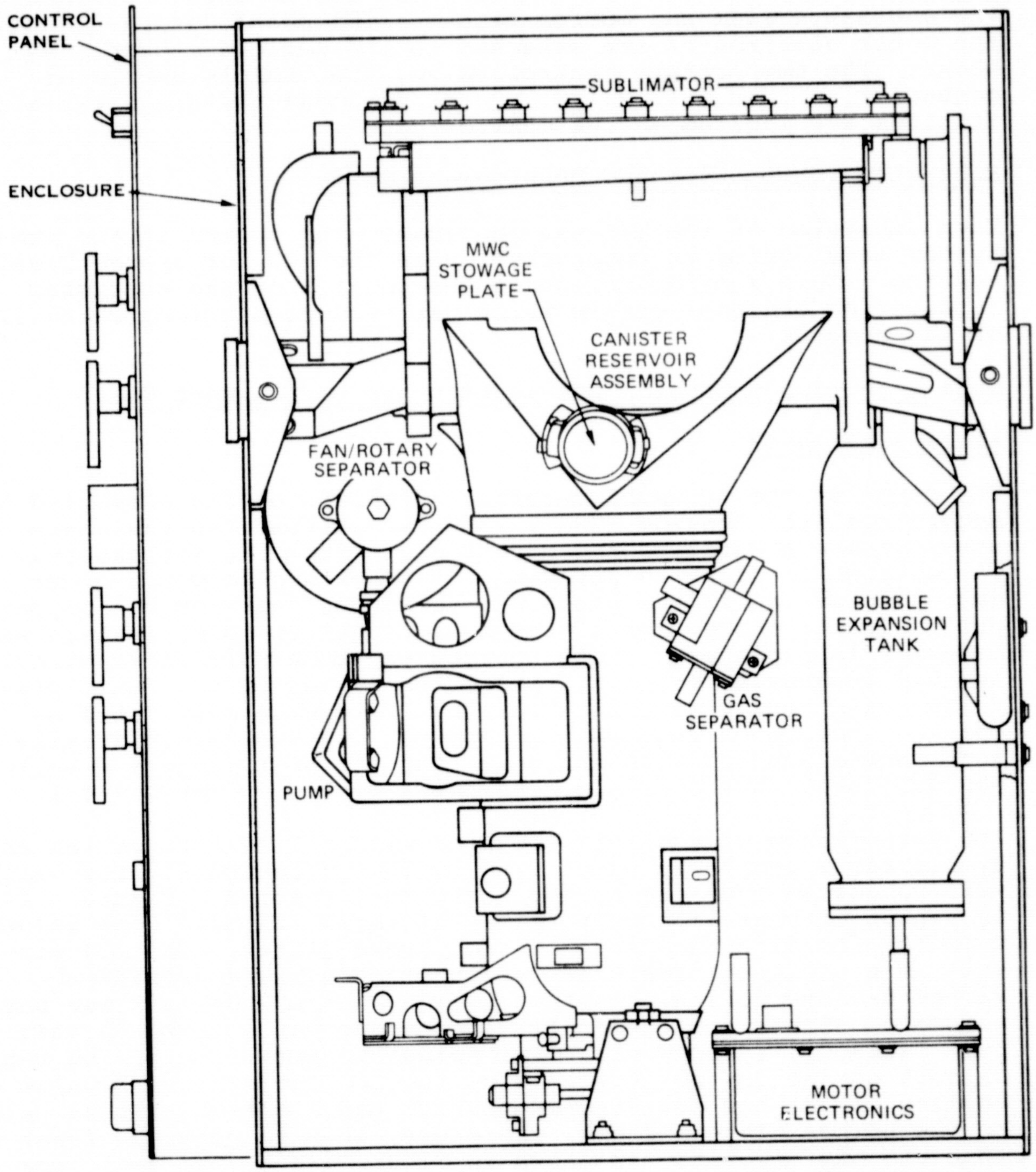
The schematic of the TCS which resulted from the combination of the HRS, HCS, WTS, and WMS is shown in Figure 4-3-20. Figure 4-3-21 shows the packaging arrangement for the TCS.

The enclosure is made up of aluminum panels which are painted white.



TCS SCHEMATIC

FIGURE 4-3-20



TCS PACKAGING ARRANGEMENT

FIGURE 4-3-21

4.3.5 (Continued)

The sublimator fan/rotary separator pump and gas separator are mounted on the canister reservoir which is, in turn, attached to the enclosure side and bottom panels. The bubble expansion tank and motor electronics are attached to the enclosure panels as shown. The temperature control valve, the vehicle umbilical connector, all shutoff valves, quick disconnects, and interface fittings are located on the control panel.

4.4 Subsystem Fabrication and Development Tests

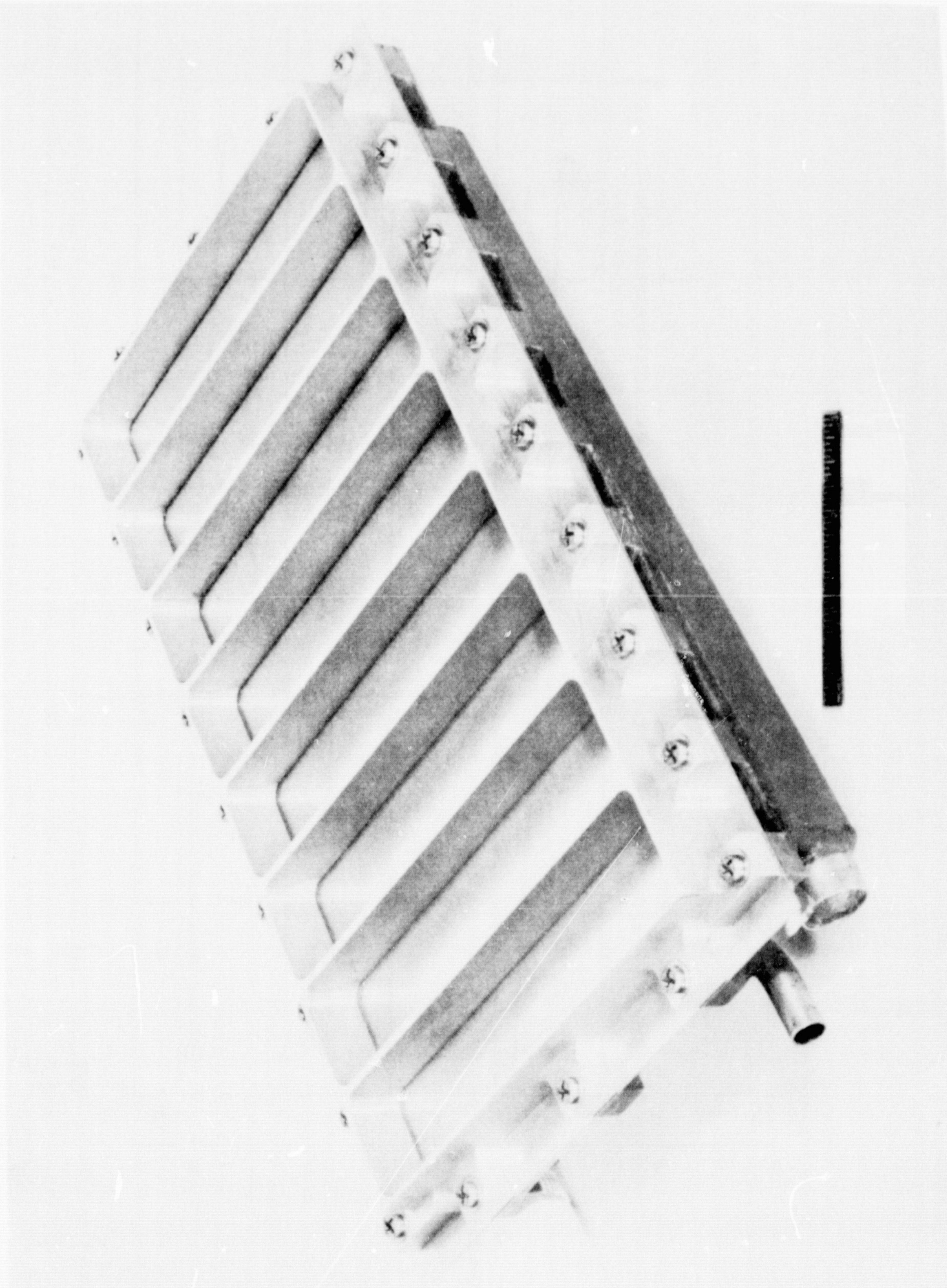
Each subsystem of the TCS was fabricated and tested at the subsystem level prior to incorporation in the TCS for system level testing. This section discusses the details of the subsystem fabrication and test effort which was conducted during Phase II of the program.

4.4.1 Heat Rejection Subsystem Fabrication and Development Test

First Sublimator

The first of the two sublimators was fabricated and assembled in accordance with drawing SVSK 87320, except that the stainless steel screen separating the porous plate from the support grid was deleted in order to determine if breakthrough would occur during operation if the plate was not separated from the support grid. During inspection of the heat exchanger core, leakage was observed in the braze joints between the transport water circuit and the feed water circuit. Since the design of this unit prevented weld repair in this area, the leaks were eliminated by coating the LCG circuit with an epoxy. The sublimator details were then assembled with the core, and the unit (Figure 4-4-1) was subjected to the development tests listed in Table 4-4-1.

The performance of the unit complied with all heat rejection subsystem requirements as summarized by the following figures which were generated from the steady state test results. Figure 4-4-2 is a plot of vent loop performance at various liquid loop inlet temperatures with the first of two porous plates. The LCG circuit inlet temperatures shown on the figure are approximate values because during this test series, the LCG delta T was maintained constant, and the inlet temperature was allowed to vary. (See Table D-1 in Appendix D for actual temperatures.) The gas circuit outlet dew point was below the LCG temperature because of cooling in the gas outlet header which had a direct thermal path to the porous plate and was, therefore, at a temperature lower than the LCG circuit. As shown in Figure 4-4-2, the vent loop outlet dew point was well below the required limit.



FIRST SUBLIMATOR
FIGURE 4-4-1

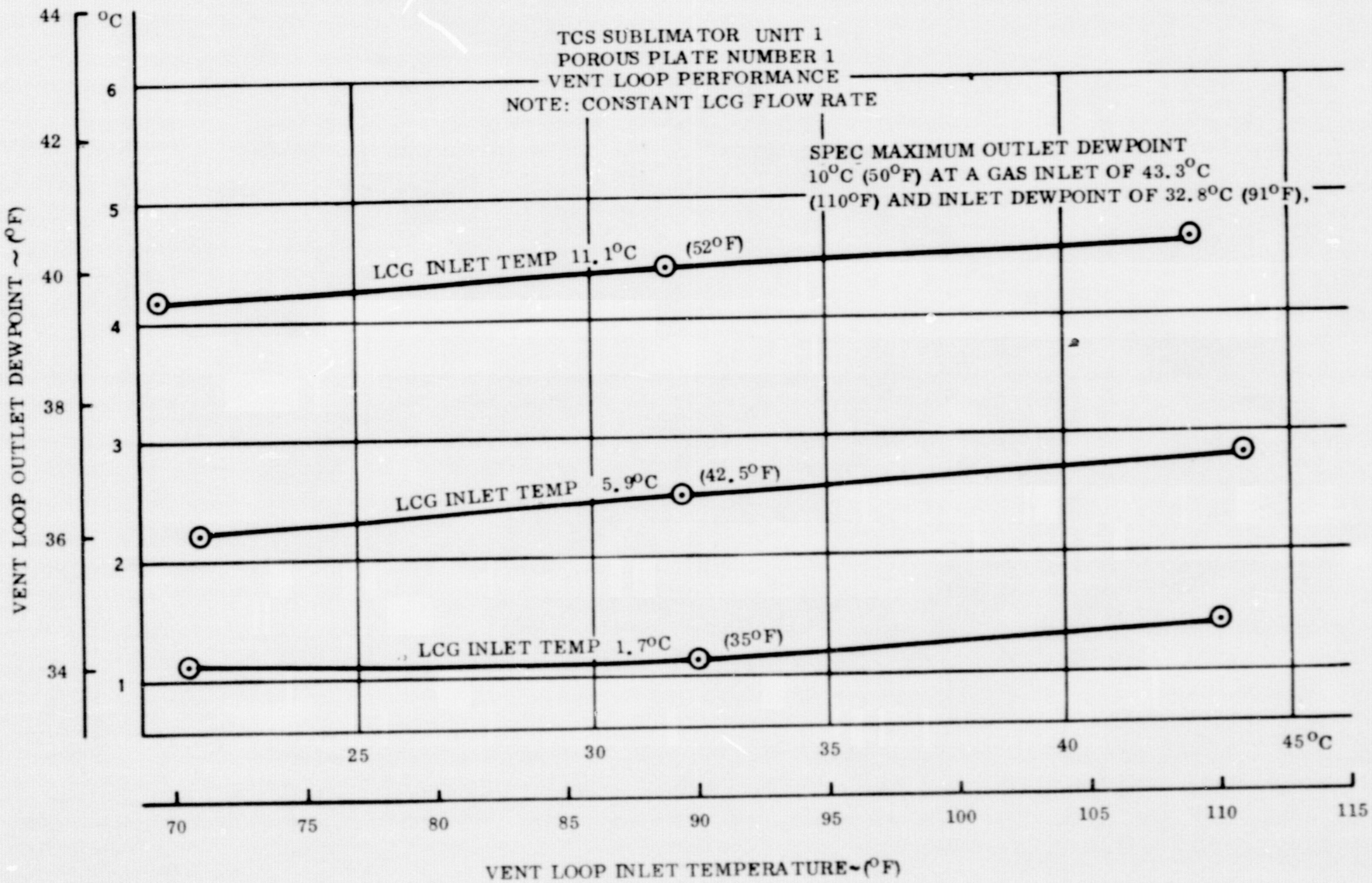

TCS SUBLIMATOR UNIT 1
POROUS PLATE NUMBER 1
VENT LOOP PERFORMANCE
NOTE: CONSTANT LCG FLOW RATE
SPEC MAXIMUM OUTLET DEWPOINT
10°C (50°F) AT A GAS INLET OF 43.3°C
(110°F) AND INLET DEWPOINT OF 32.8°C (91°F).
LCG INLET TEMP 11.1°C (52°F)
LCG INLET TEMP 5.9°C (42.5°F)
LCG INLET TEMP 1.7°C (35°F)
VENT LOOP OUTLET DEWPOINT ~ (°F)
°C
VENT LOOP INLET TEMPERATURE ~ (°F)
45°C

FIGURE 4-4-2

TABLE 4-4-1

HRS TEST SUMMARY
FIRST SUBLIMATOR (SVSK 87320)

Test	Configuration	Performance Data Location
Examination of Product	Unit 1, Plate 1	N/A
Proof Pressure	Unit 1, Plate 1	N/A
Leakage	Unit 1, Plate 1	N/A
Steady State Test	Unit 1, Plate 1	Appendix D, Table D-1
Mission Test Venting	Unit 1, Plate 1	Appendix D, Tables D-2, 3 & 4
Mission Test Non Venting	Unit 1, Plate 1	Appendix D, Table D-5
OFF Design Tests	Unit 1, Plate 1	paragraph 4.4.1
Service	Unit 1, Plate 1	N/A
OFF Design Tests	Unit 1, Plate 2	paragraph 4.4.1
Steady State Test	Unit 1, Plate 2	Appendix D, Table D-6
Mission Test Venting	Unit 1, Plate 2	Appendix D, Tables D-7, 8 & 9
Leakage Test	Unit 1, Plate 2	N/A

4.4.1 (Continued)

Figure 4-4-3 is a plot of LCG circuit performance at various vent loop inlet conditions. As shown, the LCG circuit complies with requirements at the maximum specified inlet temperature. Figure 4-4-4 shows the heat load at various inlet conditions. The load shown is a total of the LCG circuit load, the vent circuit sensible load, and the vent circuit latent load. These loads were determined as follows.

Note: All calculations were made in English units with results converted to SI units for tabulating and plotting, therefore, the equations shown are in English units.

<u>LCG Circuit Load</u>

$$\underset{(Btu/Hr)}{Q_{LCG}} = \underset{(Lb/Hr)}{W_{LCG}} \times \underset{(Btu/Lb\text{-}^{o}F)}{C_p} \times \underset{(^{o}F)}{(T_{LCG_{in}} - T_{LCG_{out}})}$$

The load in Btu/Hr was converted to the SI equivalent (watts) by dividing the load by 3.41.

<u>Vent Circuit Sensible Load</u>

$$\underset{(Btu/Hr)}{Q_{Sens}} = \underset{(Lb/Hr)}{\text{Mass Gas Out}} \times \underset{(Btu/Lb\text{-}^{o}F)}{C_p} \times \underset{(^{o}F)}{(T_{vent_{in}} - T_{vent_{out}})}$$

(C_p for Gas = .24)

<u>Vent Circuit Latent Load</u>

$$\underset{(Btu/Hr)}{Q_{Latent}} = \underset{(Lb/Min)}{(\text{Mass } H_2O_{in} - \text{Mass } H_2O_{out})} \times \underset{(Min/Hr)}{60} \times \underset{(Btu/Lb)}{h_{fg}}$$

$$\underset{(Lb/Min)}{\text{Mass } H_2O_{in}} = \frac{\text{Inlet Flow (CFM)}}{V_{in}}, \quad \text{Mass } H_2O_{out} = \frac{\text{Outlet Flow CFM}}{V_{out}}$$

where:

V_{in} = Specific volume @ inlet dew point, Ft^3/Lb_m

V_{out} = Specific volume @ outlet dew point, Ft^3/Lb_m

h_{fg} = Heat of vaporization at average dew point temperature, Btu/Lb_m

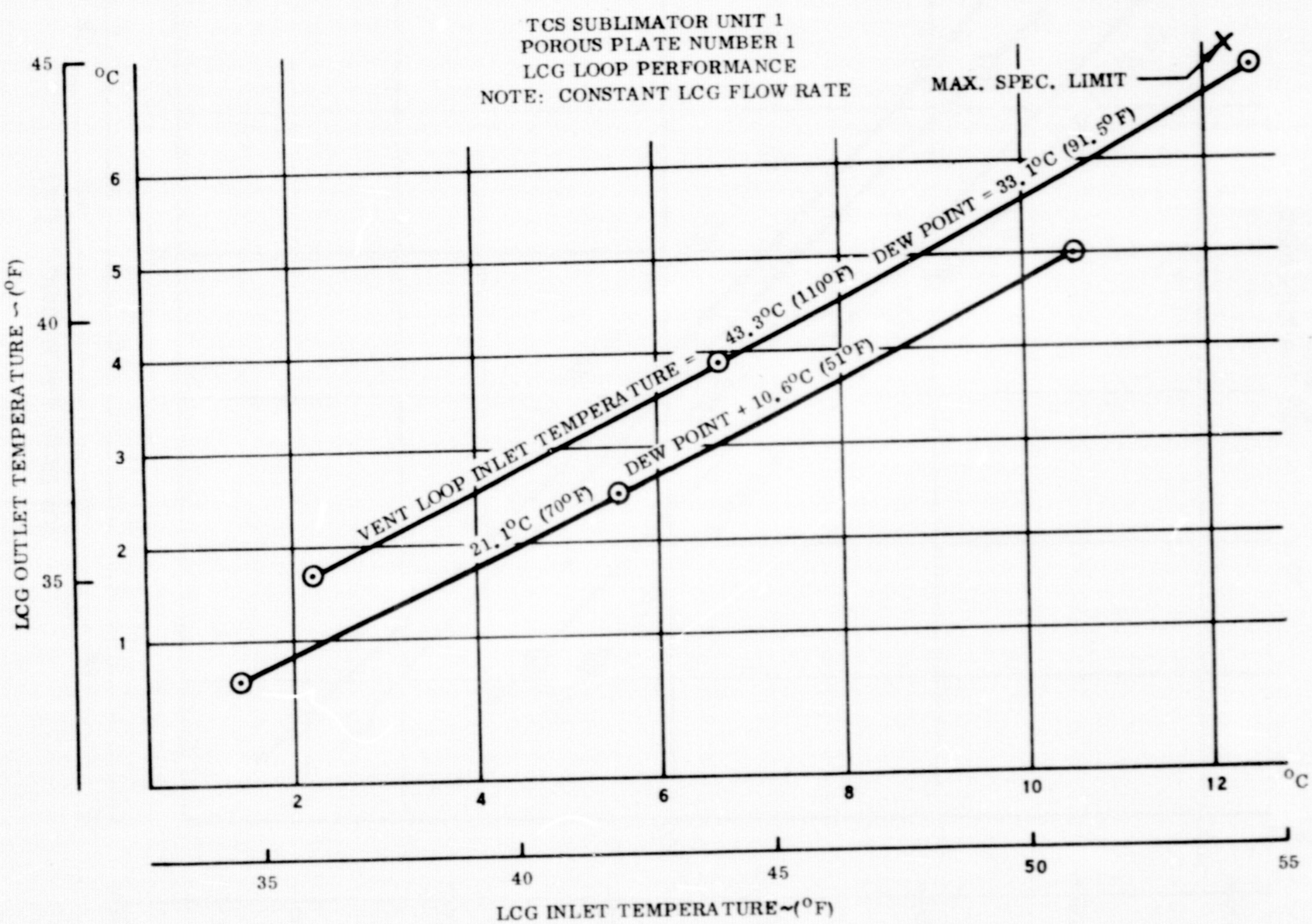

TCS SUBLIMATOR UNIT 1
POROUS PLATE NUMBER 1
LCG LOOP PERFORMANCE
NOTE: CONSTANT LCG FLOW RATE
MAX. SPEC. LIMIT
VENT LOOP INLET TEMPERATURE = 43.3°C (110°F) DEW POINT = 33.1°C (91.5°F)
21.1°C (70°F) DEW POINT + 10.6°C (51°F)
LCG OUTLET TEMPERATURE ~(°F)
°C
45
40
35
1
2
3
4
5
6
2
4
6
8
10
12
35
40
45
50
55
LCG INLET TEMPERATURE~(°F)

FIGURE 4-4-3

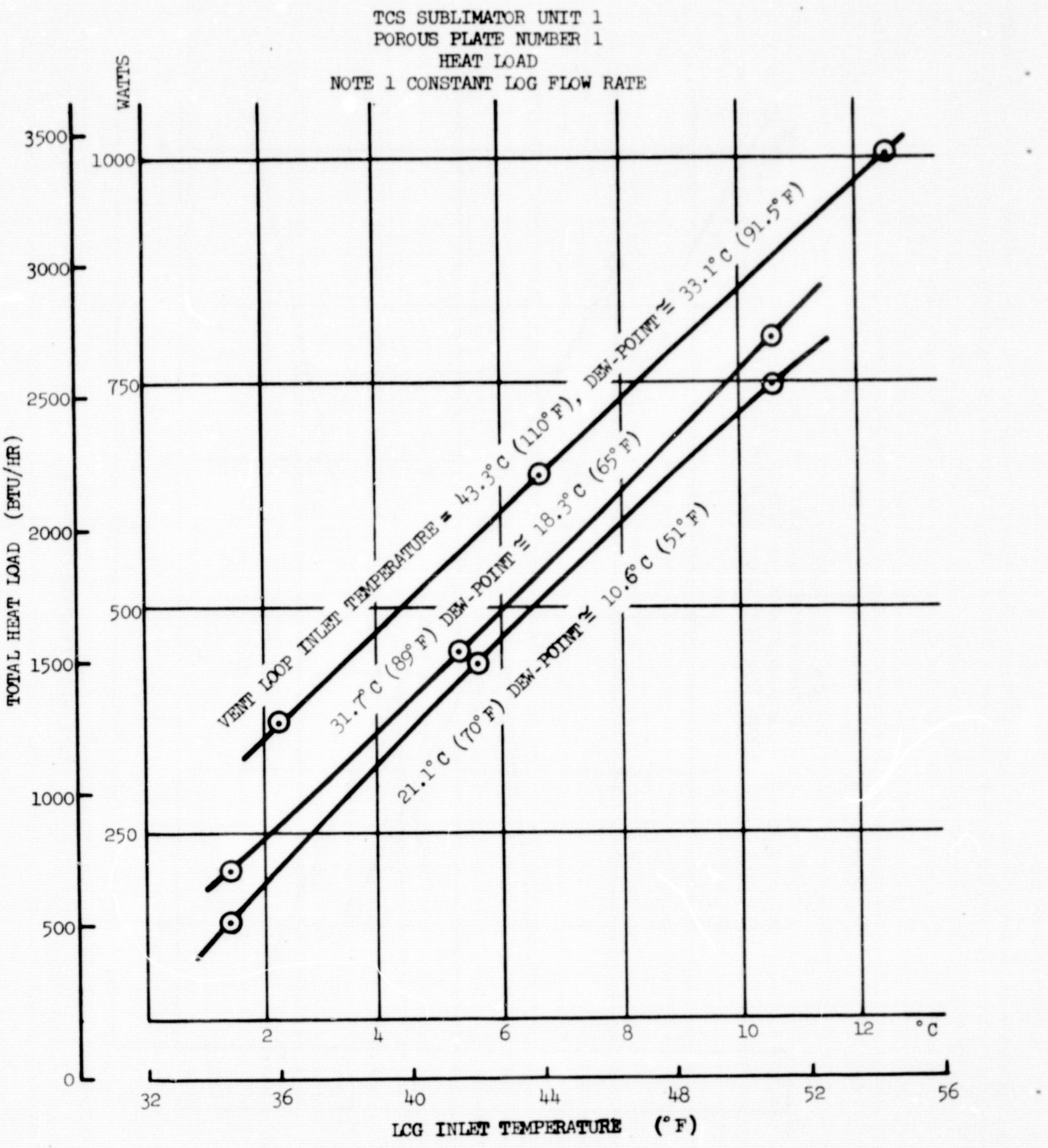

TCS SUBLIMATOR UNIT 1
POROUS PLATE NUMBER 1
HEAT LOAD
NOTE 1 CONSTANT LCG FLOW RATE
WATTS
TOTAL HEAT LOAD (BTU/HR)
VENT LOOP INLET TEMPERATURE = 43.3°C (110°F), DEW-POINT ≅ 33.1°C (91.5°F)
31.7°C (89°F) DEW-POINT ≅ 18.3°C (65°F)
21.1°C (70°F) DEW-POINT ≅ 10.6°C (51°F)
°C
LCG INLET TEMPERATURE (°F)

FIGURE 4-4-4

4.4.1 (Continued)

Figure 4-4-5 through Figure 4-4-7 present comparable performance data for the sublimator when tested with porous plate number two. The performance when using plate two complies with the Work Statement requirements.

During all operational tests of the unit, moisture collected in the inlet header of the sublimator. It was found that this was caused by condensation because the walls of the header were at a low temperature due to heat transfer directly to the porous plate region of the unit. The changes necessary to minimize condensation in the inlet header and to remove any condensate which might occur were incorporated in the second sublimator.

In addition, the slurper performance was less than expected (87-94% efficiency vs an expected 100%). Subsequent slurper module testing revealed that the slurper configuration incorporated in the first sublimator was not capable of operating at 100% efficiency. These slurper module tests did result in definition of a slurper configuration that could operate at 100% efficiency, and a slurper of this configuration was incorporated in the second sublimator.

The sublimator test program was conducted in accordance with Test Plan TCS-001 which is included in Appendix C and consisted of the following tests.

<u>HRS Examination of Product</u> (Unit 1, Plate 1)

There was no significant visual defects noted, and the unit complied with drawing SVSK 87320, except that the stainless steel screen between the porous plate and grid was deleted.

<u>HRS Proof Pressure</u> (Unit 1, Plate 1)

The gas circuit was pressurized to 42 KPa (6.1 psig) for five minutes with no visible deformation. The liquid circuit was pressurized to 370 KPa (54 psig) for five minutes with no evidence of deformation.

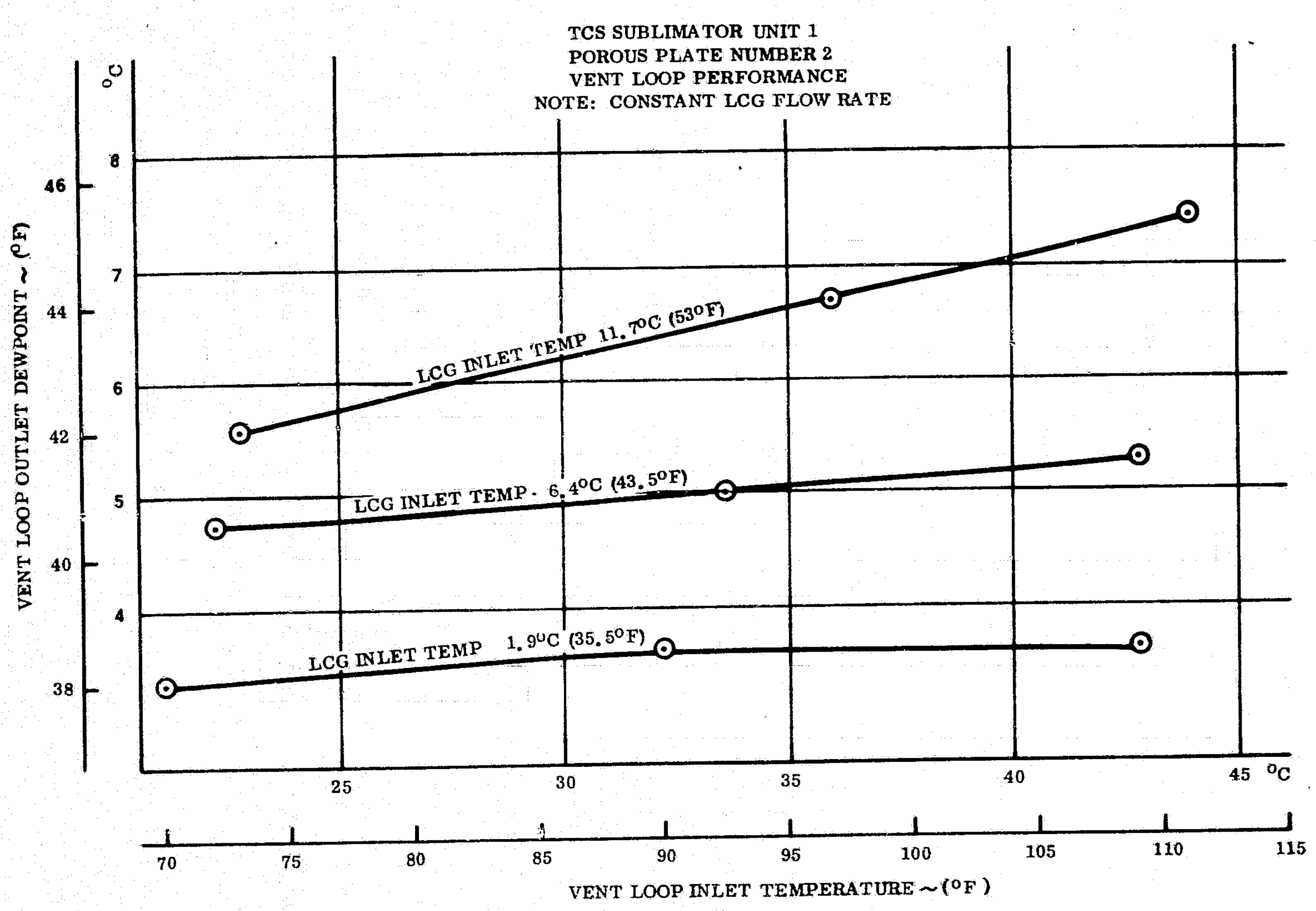

TCS SUBLIMATOR UNIT 1
POROUS PLATE NUMBER 2
VENT LOOP PERFORMANCE
NOTE: CONSTANT LCG FLOW RATE
LCG INLET TEMP 11.7°C (53°F)
LCG INLET TEMP - 6.4°C (43.5°F)
LCG INLET TEMP 1.9°C (35.5°F)
°C
8
7
6
5
4
46
44
42
40
38
VENT LOOP OUTLET DEWPOINT ~ (°F)
25
30
35
40
45
°C
70
75
80
85
90
95
100
105
110
115
VENT LOOP INLET TEMPERATURE ~ (°F)

FIGURE 4-4-5

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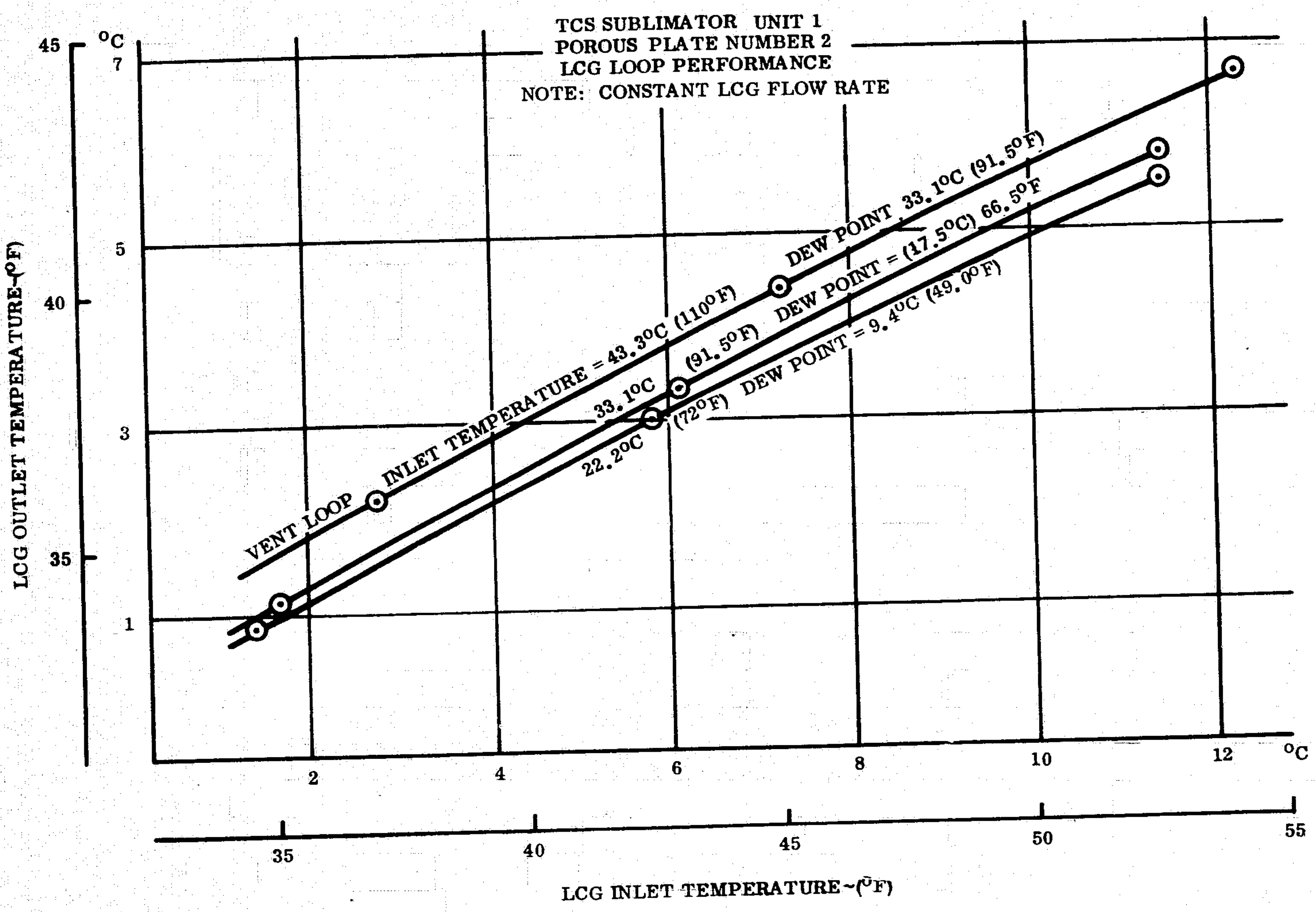


FIGURE 4-4-6

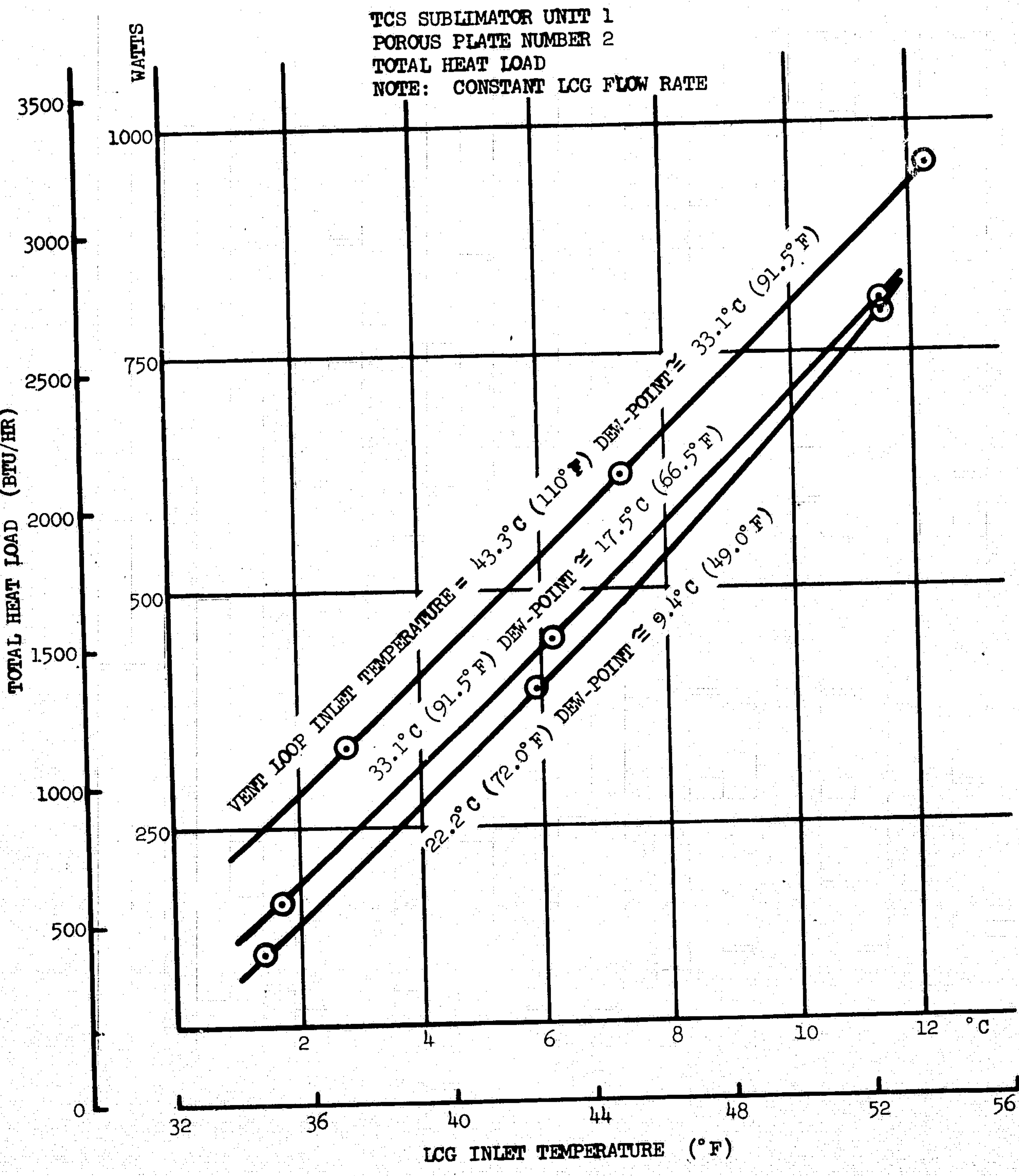

TCS SUBLIMATOR UNIT 1
POROUS PLATE NUMBER 2
TOTAL HEAT LOAD
NOTE: CONSTANT LCG FLOW RATE
WATTS
1000
750
500
250
3500
3000
2500
2000
1500
1000
500
0
TOTAL HEAT LOAD (BTU/HR)
VENT LOOP INLET TEMPERATURE = 43.3°C (110°F) DEW-POINT ≅ 33.1°C (91.5°F)
33.1°C (91.5°F) DEW-POINT ≅ 17.5°C (66.5°F)
22.2°C (72.0°F) DEW-POINT ≅ 9.4°C (49.0°F)
2
4
6
8
10
12
°C
32
36
40
44
48
52
56
LCG INLET TEMPERATURE (°F)

FIGURE 4-4-7

4.4.1 (Continued)

HRS Leakage (Unit 1, Plate 1)

The gas circuit was pressurized to 28.8 KPa (4.2 psig), and the unit was submerged in water for 20 minutes. There was no evidence of leakage. The liquid circuit was pressurized to 247 KPa (36 psig), and the unit was submerged in water for 20 minutes. There was no evidence of leakage.

HRS Steady State Test (Unit 1, Plate 1)

The liquid and gas loop inlet conditions were established, and the feed water flow was initiated. After start up, the performance was determined at various liquid loop and gas loop inlet conditions. The result of these tests and a summary of the Work Statement requirements are included in Appendix D.

During the initial steady state performance testing, it was not possible to start up at high heat load without breakthrough. This was corrected by replacing the metallic shims which establish the feed water gap with a nonmetallic gasket and by adding nonmetallic spacers between the porous plate and the heat transfer surface. After this change, the unit was compliant with all of the performance requirements of the Work Statement. The length of this test necessitated several start up and shutdown cycles. Thus, the unit was subjected to both nominal and worst case start up conditions. Under nominal conditions (gas inlet temperature 22.5°C (72.5°F), inlet dew point 12.78°C (55°F), and liquid inlet temperature 12.5°C (54.5°F)), the liquid loop outlet temperature dropped below 7.22°C (45°F) within 30 seconds. Under extreme hot start up conditions (gas inlet 43.86°C (111°F), dew point 31.95°C (89.5°F), and liquid inlet temperature 38.89°C (102°F)), the liquid loop outlet temperature dropped below 7.22°C (45°F) in approximately five minutes. At a low heat load, 115 watts (~530 Btu/hr) shutdown was accomplished in approximately four minutes, while at high heat loads, 880 watts (~3,000 Btu/hr) shutdown was accomplished in approximately one minute.

HRS Mission Test - Venting (Unit 1, Plate 1)

The liquid and gas loop inlet conditions were established at typical Pre-EVA levels, and the feed water flow was initiated. After start up, the inlet conditions were varied to simulate typical metabolic loads, and the performance of the unit was monitored. Three mission tests in the venting mode were conducted. A summary of the sublimator performance for each mission cycle is included in Appendix D. The unit performed in accordance with the Work Statement requirements.

4.4.1 (Continued)

HRS Mission Test Non-Venting (Unit 1, Plate 1)

The liquid loop inlet flow and temperature were set at values representative of umbilical operation, and the gas loop conditions were varied to simulate typical metabolic loads, and the performance was monitored. A summary of the data is included in Appendix D. The unit performed in accordance with the Work Statement requirements.

HRS Off Design Tests (Unit 1, Plate 1)

The following Off Design Tests were conducted:

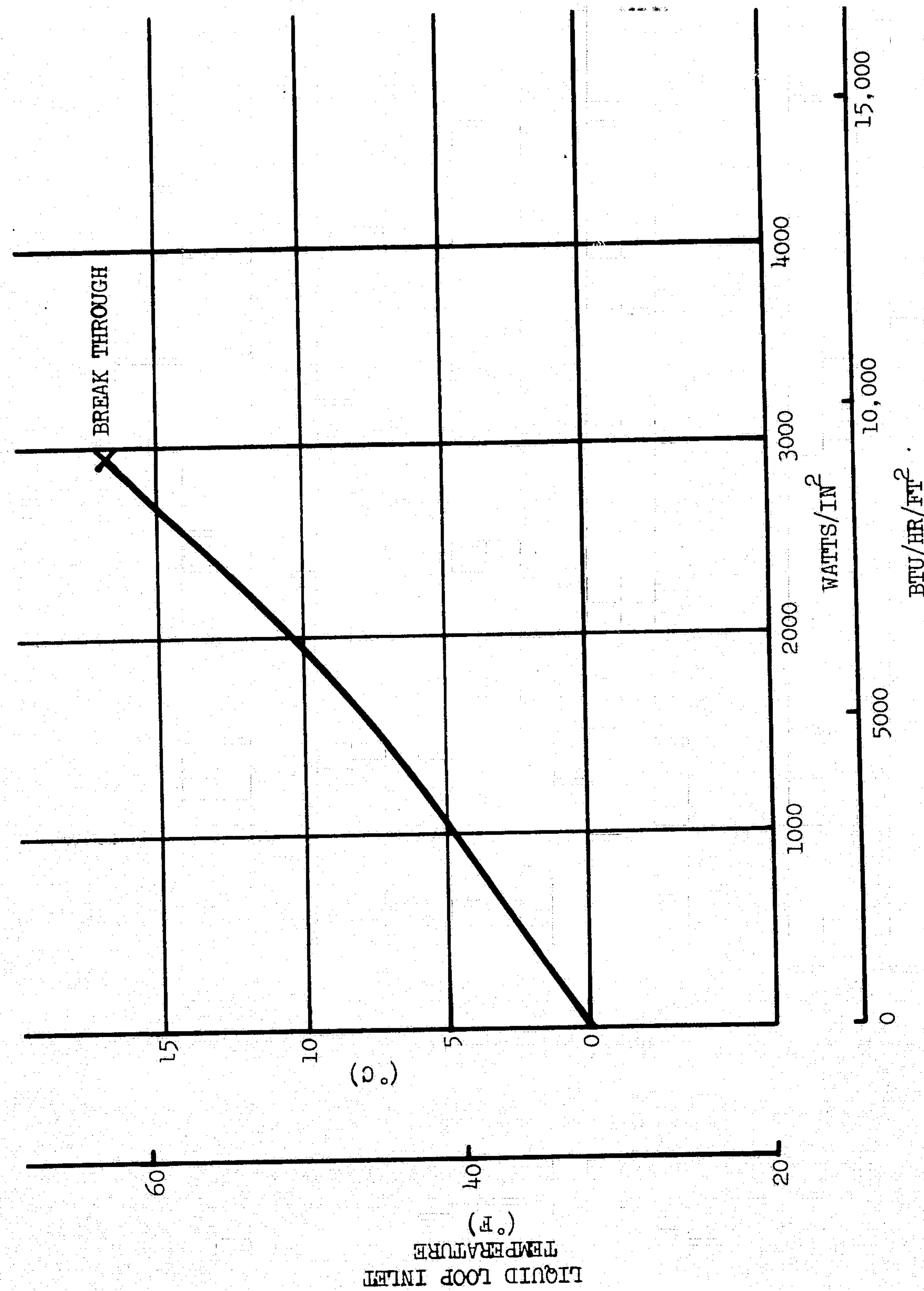
- Exposure to vacuum with pre-wetted plate
- Performance at increased gas flow
- Performance at increased liquid thermal load
- Performance with "o" ring removed from between plate and heat transfer surface

For the first test, the porous plate was wetted, the vent loop and liquid loop inlet conditions were established, the chamber was evacuated, the feed water flow was initiated, and the performance was observed. There was no apparent difference in performance from previous runs.

The gas flow was increased to 38.5×10^{-4} M3/Sec (8.2 CFM) and then to 56.4×10^{-4} M3/Sec (12 CFM) and performance was observed. Other than the expected increase in latent and sensible heat loads, there was no change in performance.

The gas loop flow was returned to nominal, and the inlet temperature and dew point were maintained at the upper limit (T gas in = 43.33°oC (110°F) T_{DP} in = 32.22 (90°F)), and the liquid inlet temperature was increased until breakthrough occurred. A plot of heat load vs the liquid loop inlet temperature is included in Figure 4-4-8. During this test series, air was introduced into the feed water in approximately 2CC slugs. There was no noticeable affect in performance.

The unit was disassembled, and the "o" ring between the porous plate and the heat transfer surface was removed leaving the non-metallic spacer, used to establish the feed water gap, as a gasket. The unit was reassembled and testing resumed. The liquid loop and gas loop inlet conditions were set at nominal start up values T gas in = 36.11°C (97°F), DP in 28.06°C (82.5°F) and T liquid in = 11.11°C (52°F), and the feed water flow was initiated. At start up, a small amount of ice extrusion was



Total Heat Rejected vs. Liquid Loop Inlet Temperature

Figure 4-4-8

4.4.1 (Continued)

observed at the plate/heat exchanger interface; however, within about 5 minutes, no additional ice appeared. Thus, it was concluded that an adequate seal can be obtained with a gasket making it possible to eliminate the "o" ring in future units.

HRS Service (Unit 1, Plate 1)

Porous plate No. 1 (Figure 4-4-9) was removed from the unit, and the plate and heat transfer surface were visually examined. There was no evidence of pitting on either the plate or the heat transfer surface. There was some discoloration in areas on the plate which was attributed to deposits of silver bromide.

During the testing with porous plate No. 1, condensation occurred in the gas inlet header. This was induced by a low temperature in the header which resulted from low thermal resistance between the header and the porous plate. In order to increase this resistance during testing with porous plate No. 2, an undersized gasket was incorporated to eliminate heat rejection in the area above the inlet header. The use of this gasket resulted in approximately a 5% reduction in the plate area available for heat rejection.

HRS Off Design Test (Unit 1, Plate 2)

Sublimator performance with all loads impossed by the liquid loop was determined in order to accurately determine the effects of the undersized gasket. The results of this test and a similar test using porous plate No. 1 with no gasket are plotted in Figure 4-4-10. The results showed that at a constant inlet temperature there was a 4 to 6% decrease in the heat rejected with porous plate No. 2. Considering the predicted 5% decrease in performance due to use of the undersized gasket, this test confirmed the repeatability of the sublimator plates.

HRS Steady State Test (Unit 1, Plate 2)

The liquid and gas loop inlet conditions were established, and feed water flow was initiated. After start up, the performance was determined at various liquid loop and gas loop inlet conditions. The results of these tests and a summary of the Work Statement requirements are included in Appendix D. The unit was compliant with all of the performance requirements of the Work Statement, and the performance using plate 2 was comparable to the performance achieved using porous plate No. 1 after taking into consideration the slight decrease in performance due to use of the undersized gasket.

POROUS PLATE 1
FIGURE 4-4-9

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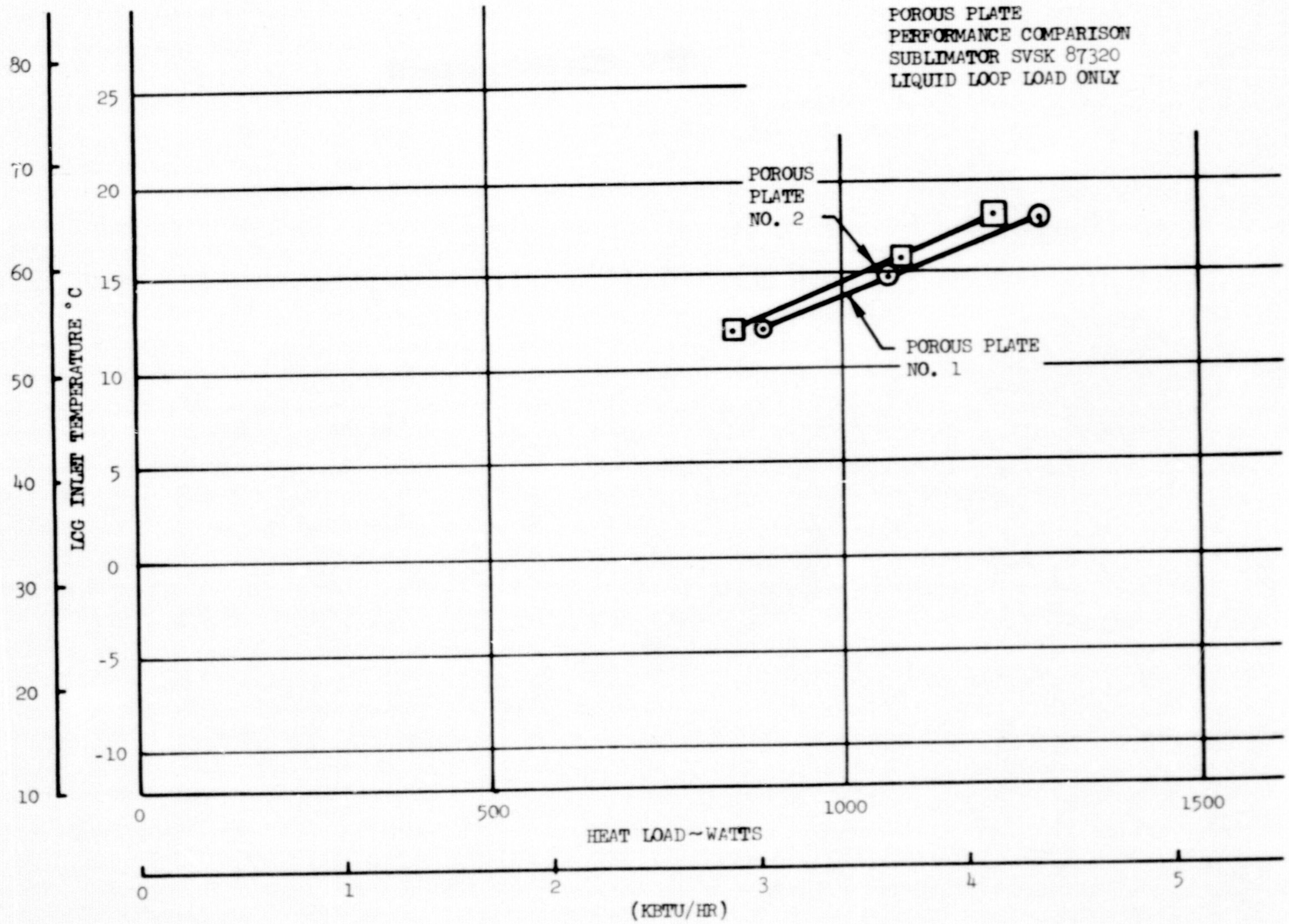


FIGURE 4-4-10

4.4.1 (Continued)

HRS Mission Test - Venting (Unit 1, Plate 2)

Typical pre-EVA liquid and gas loop inlet conditions were established, and the feed water flow was initiated. After start up, the inlet conditions were varied to typical EVA levels, and the performance of the unit was monitored. Three mission tests were conducted. A summary of the sublimator performance for each mission cycle is included in Appendix D. The unit performed in accordance with the Work Statement requirements.

HRS Leakage Test (Unit 1, Plate 2)

The gas circuit was pressurized to 41 KPa (6 psig) with nitrogen, and the unit was submerged in water for 20 minutes. There was no evidence of leakage.

The liquid circuit was pressurized to 247 KPa (36 psig) with nitrogen, and the unit was submerged in water for 20 minutes. A leak of 28 cc/min was detected between the liquid loop and the feed water circuit. The leakage test was repeated using water pressurized to various levels. The results are shown in Figure 4-4-11. At the nominal operation pressure of the liquid loop (27 KPa (4 psig)), the water leakage is less than .6 cc/hr which was considered acceptable when compared to the normal feed water use rate of ~600 cc/hr.

Second Sublimator

The second sublimator (SVSK 90302) was designed after testing of the initial unit and incorporated the refinements found possible and/or necessary during fabrication and test of the first unit.

After brazing of the heat exchanger core, leaks were detected between the transport loop and feed water circuit. These leaks were repaired by electron beam welding.

After completion of the heat exchanger core, the unit was assembled as defined by SVSK 90302 (Figure 4-4-12) using porous plate No. 2 which had been removed from the first sublimator and was subjected to the tests listed in Table 4-4-2.

The unit complied with the Work Statement requirements as shown by the vent loop and LCG performance curves (Figures 4-4-13 and 4-4-14 respectively). The vent loop outlet temperature was higher than with the first sublimator because the gas inlet and outlet headers were isolated from the porous plate and thus could not contribute to the cooling of the vent loop. Figure 4-4-15 is a plot of the heat load at various inlet conditions.

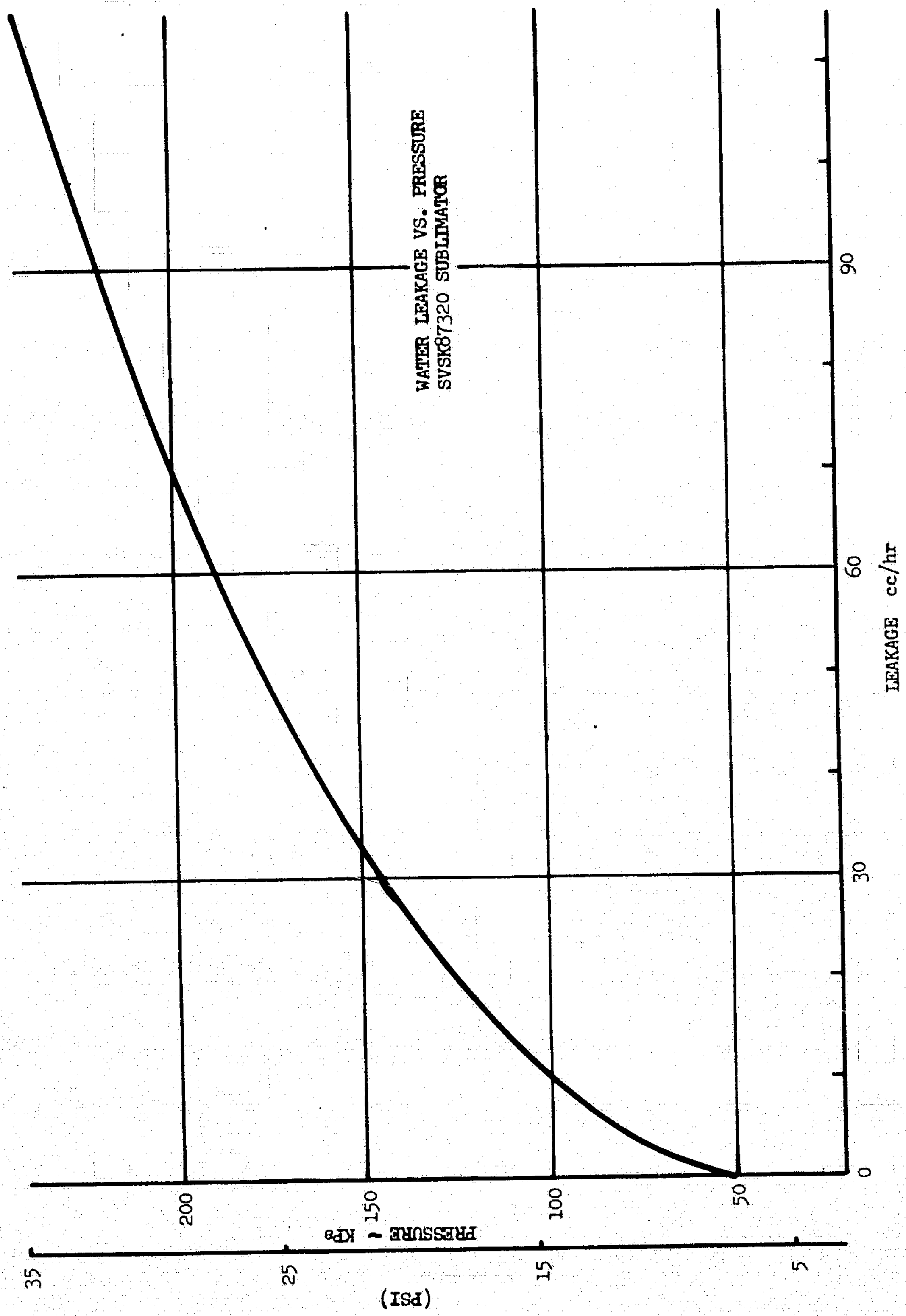
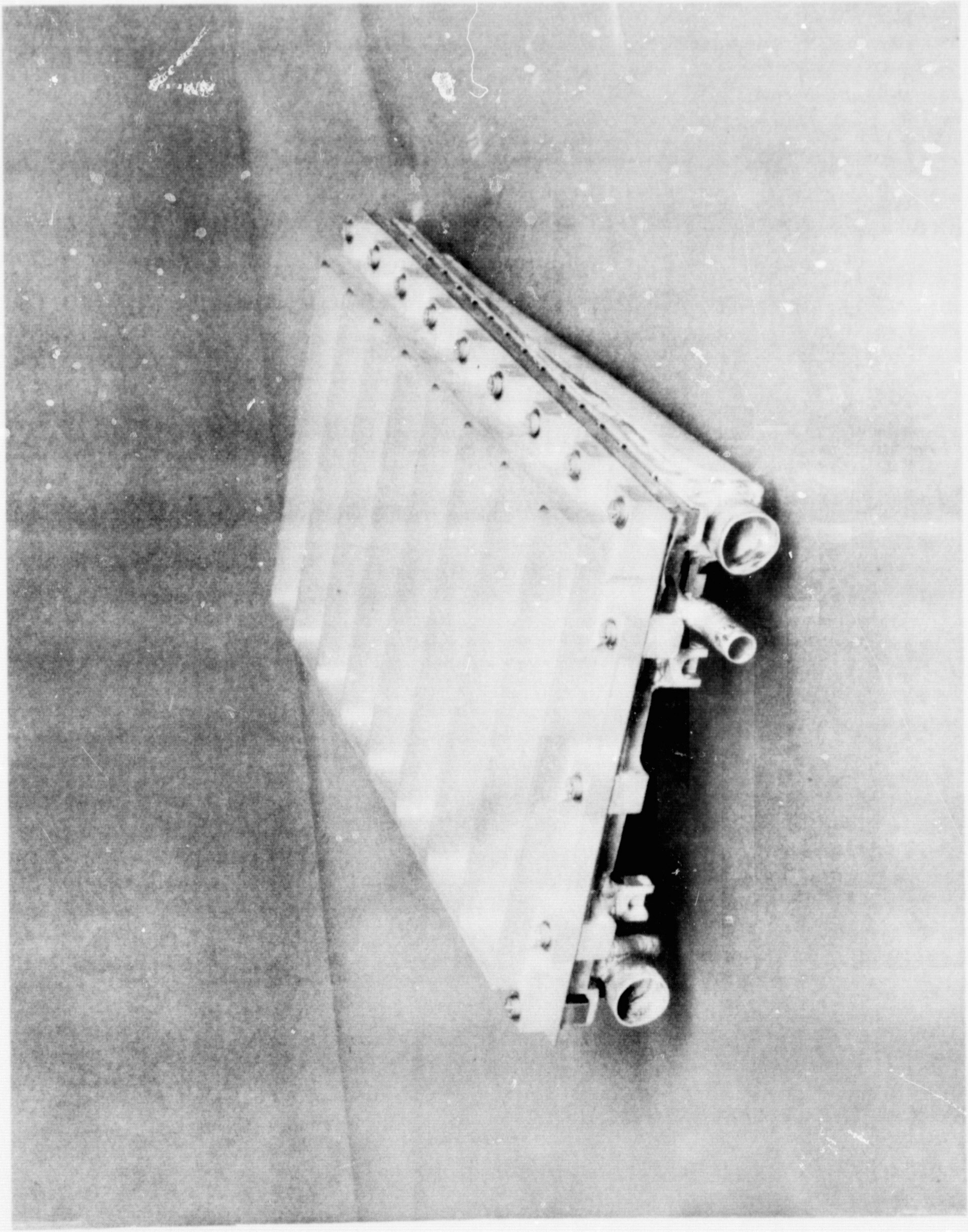

WATER LEAKAGE VS. PRESSURE
SVSK87320 SUBLIMATOR
LEAKAGE cc/hr
0
30
60
90
PRESSURE ~ KPa
50
100
150
200
(PSI)
5
15
25
35

FIGURE 4-4-11

TABLE 4-4-2

HRS TEST SUMMARY
SECOND SUBLIMATOR (SVSK-90302)

Test	Configuration	Performance Data Location
Proof	Unit 2, Plate 1	N/A
Leakage	Unit 2, Plate 1	N/A
Steady State Venting	Unit 2, Plate 1	Appendix D, Table D-10
Steady State Non Venting	Unit 2, Plate 1	Appendix D, Table D-11



SECOND GENERATION SUBLIMATOR

FIGURE 4-4-12

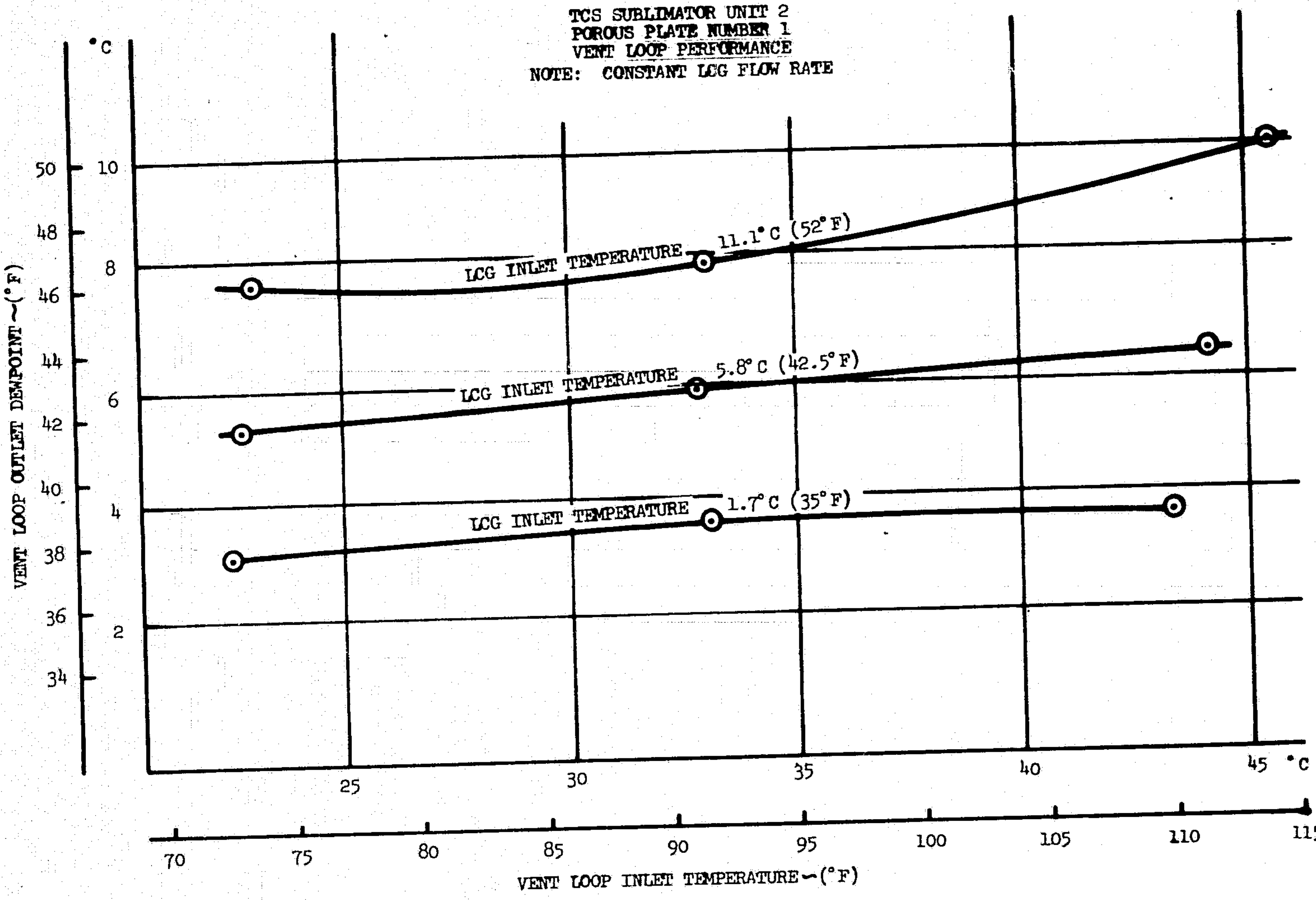


FIGURE 4-4-13

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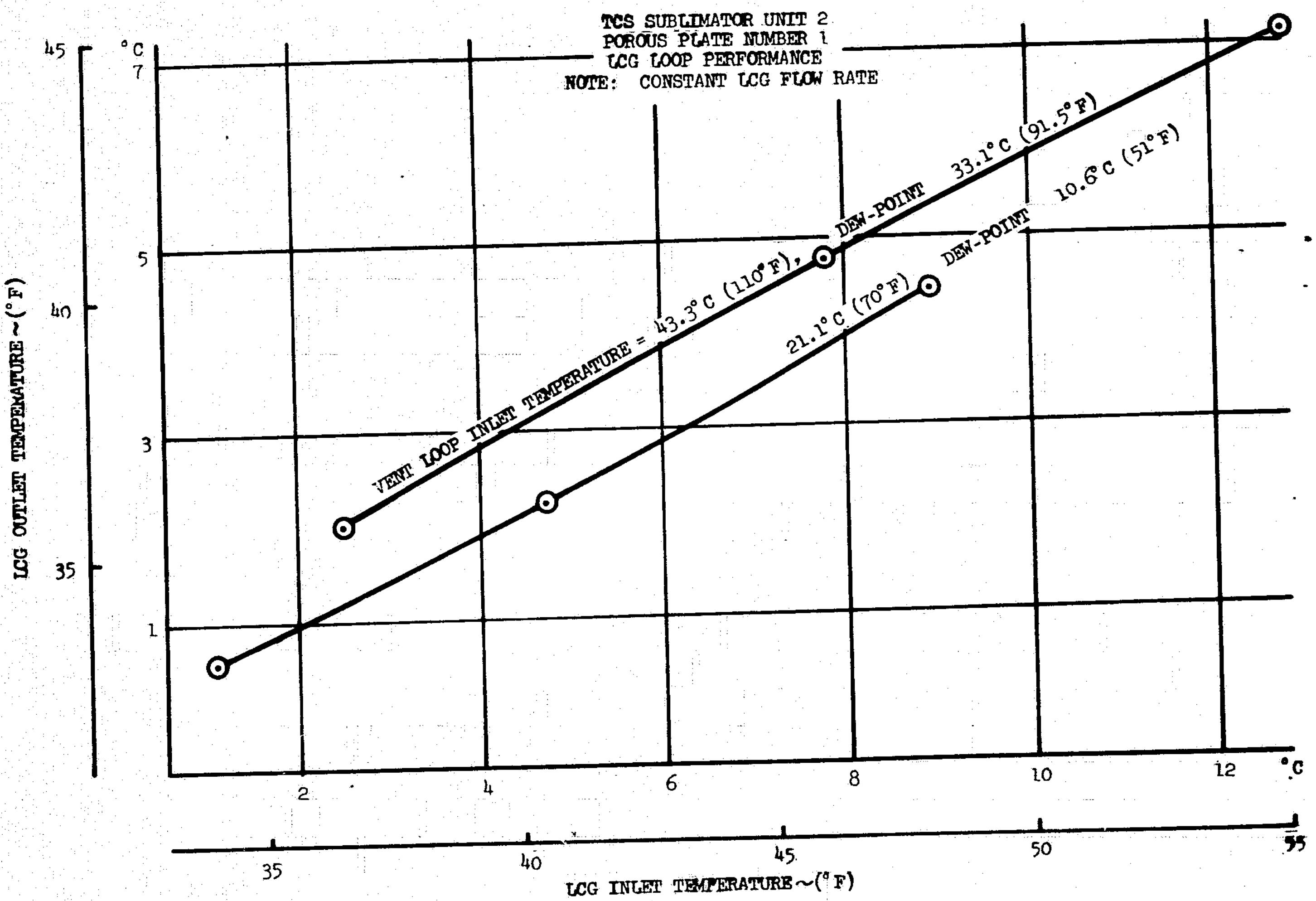


FIGURE 4-4-14

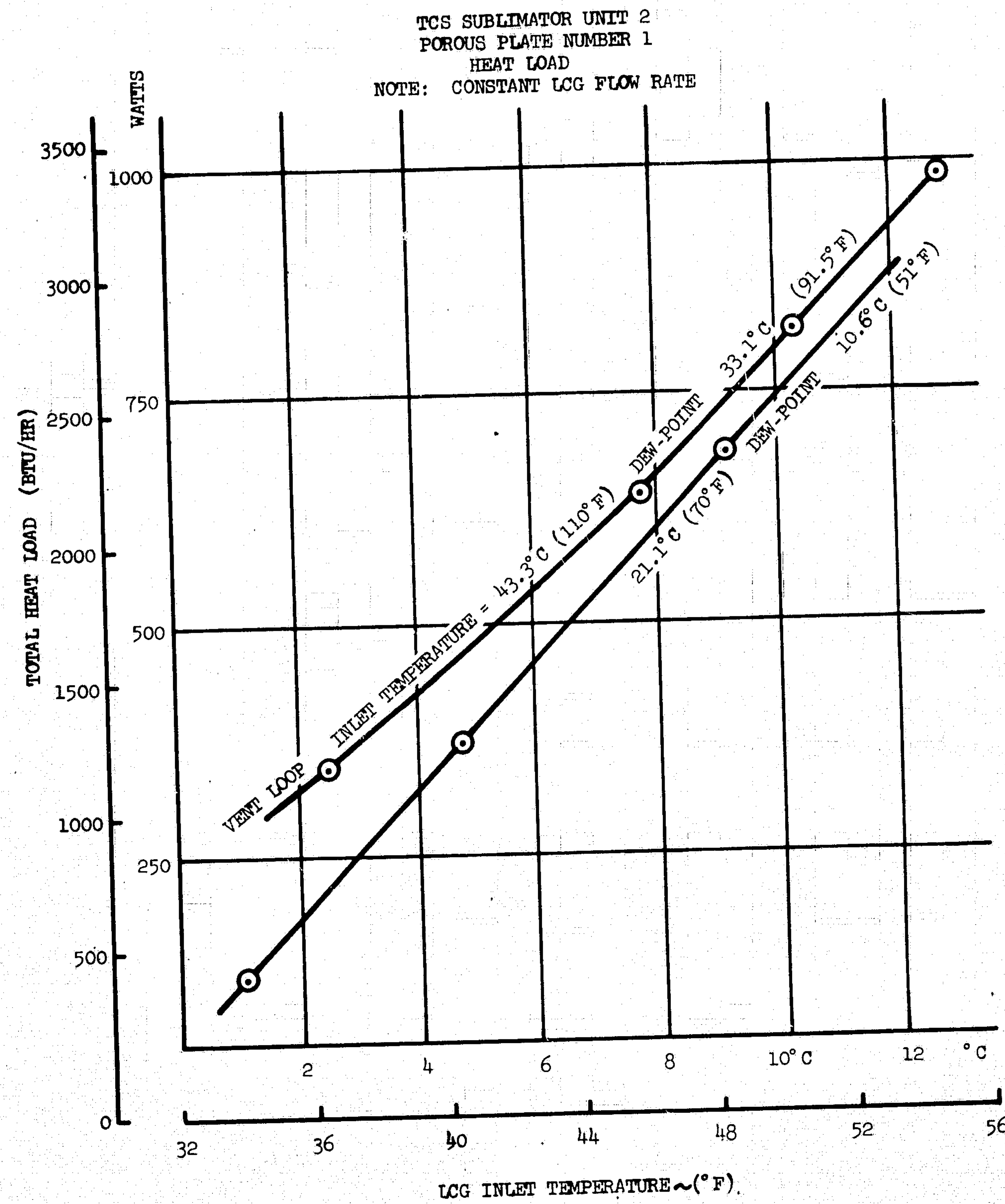

TCS SUBLIMATOR UNIT 2
POROUS PLATE NUMBER 1
HEAT LOAD
NOTE: CONSTANT LCG FLOW RATE
WATTS
1000
750
500
250
TOTAL HEAT LOAD (BTU/HR)
3500
3000
2500
2000
1500
1000
500
0
VENT LOOP INLET TEMPERATURE = 43.3°C (110°F)
DEW-POINT 33.1°C (91.5°F)
DEW-POINT 21.1°C (70°F)
10.6°C (51°F)
2
4
6
8
10° C
12
° C
32
36
40
44
48
52
56
LCG INLET TEMPERATURE ~ (°F).

FIGURE 4-4-15

4.4.1 (Continued)

After completion of the testing, the water traps placed at the inlet and outlet of the sublimator were checked and found to be free of water. The inside of the inlet and outlet headers were examined, and while the hydrophilic coating in each header was wet, there was no evidence of free water or puddling. This, plus the increase in gas temperature over the results obtained with the first sublimator, indicate that the thermal isolation of the header, the addition of the small slurper to the inlet header and the changes to the slurper configuration have eliminated deficiences observed during testing of the first unit.

Testing of the sublimator consisted of the following tests.

<u>HRS Examination of Product</u> (Unit 2, Plate 1)

There were no significant visual defects noted, and the unit complied with drawing SVSK 90302.

<u>HRS Proof Pressure</u> (Unit 2, Plate 1)

The gas circuit was pressurized to 41 KPa (6.0 psig) for five minutes with no visible deformation. The liquid circuit was pressurized to 370 KPa (54 psig) for five minutes with no evidence of deformation.

<u>HRS Leakage</u> (Unit 2, Plate 1)

The gas circuit was pressurized to 27.4 KPa (4.0 psig), and the unit was submerged in water for 20 minutes. A small leak was detected near the slurper header cover. The cover was removed, and the sealing surface was reworked to remove some scratches which extended across the sealing surface. The header cover was reinstalled, and the leakage test was repeated with no evidence of leakage. The liquid circuit was then pressurized to 247 KPa (36 psig), and the unit was submerged in water for 20 minutes. A small leak was detected in the weld near one of the gas headers. This leak was repaired with an epoxy (EC2216), and the leakage test was repeated with no further evidence of leakage.

<u>HRS Steady State - Venting</u> (Unit 2, Plate 1)

The liquid and gas loop inlet conditions were established, and the feed water flow was initiated. After start up, the performance was determined at various liquid loop and gas loop inlet conditions. The result of this test and a summary of the Work Statement requirements are included in Appendix D.

4.4.1 (Continued)

HRS Steady State - Non-Venting (Unit 2, Plate 1)

The liquid loop inlet flow and temperature were set at values representative of umbilical operation, the gas inlet temperature was maintained at the maximum level, and the dew point was stabilized at low, intermediate, and high levels to determine the performance of the unit. The results of this are included in Appendix D.

4.4.2 Humidity Control Subsystem Fabrication and Development Test

The HCS consists of two stages. The first stage is the slurper which is an integral part of the sublimator and was tested during the HRS development test program. The second stage is a rotary separator driven by the fan motor. The separator details consisting of a pitot, drum, and housing were assembled to a fan assembly comprised of an Apollo PLSS fan bearing assembly, impellor and volute and a Hamilton Standard DC motor capable of fan operation over a pressure range of 27.6 KPa (4.0 psia) to 129 KPa (18.7 psia). The unit was assembled in accordance with drawing SVSK 87343 (Figure 4-4-16) and was subjected to the following development test program.

HCS Examination of Product

There were no significant visual defects noted, and the unit was found to comply with the engineering definition of the as-built configuration.

HCS Proof Pressure

The gas circuit was pressurized to 41.3 KPa (6 psig) for six minutes with no visible deformation. The liquid circuit was pressurized to 372 KPa (54 psig) for five minutes with no evidence of deformation.

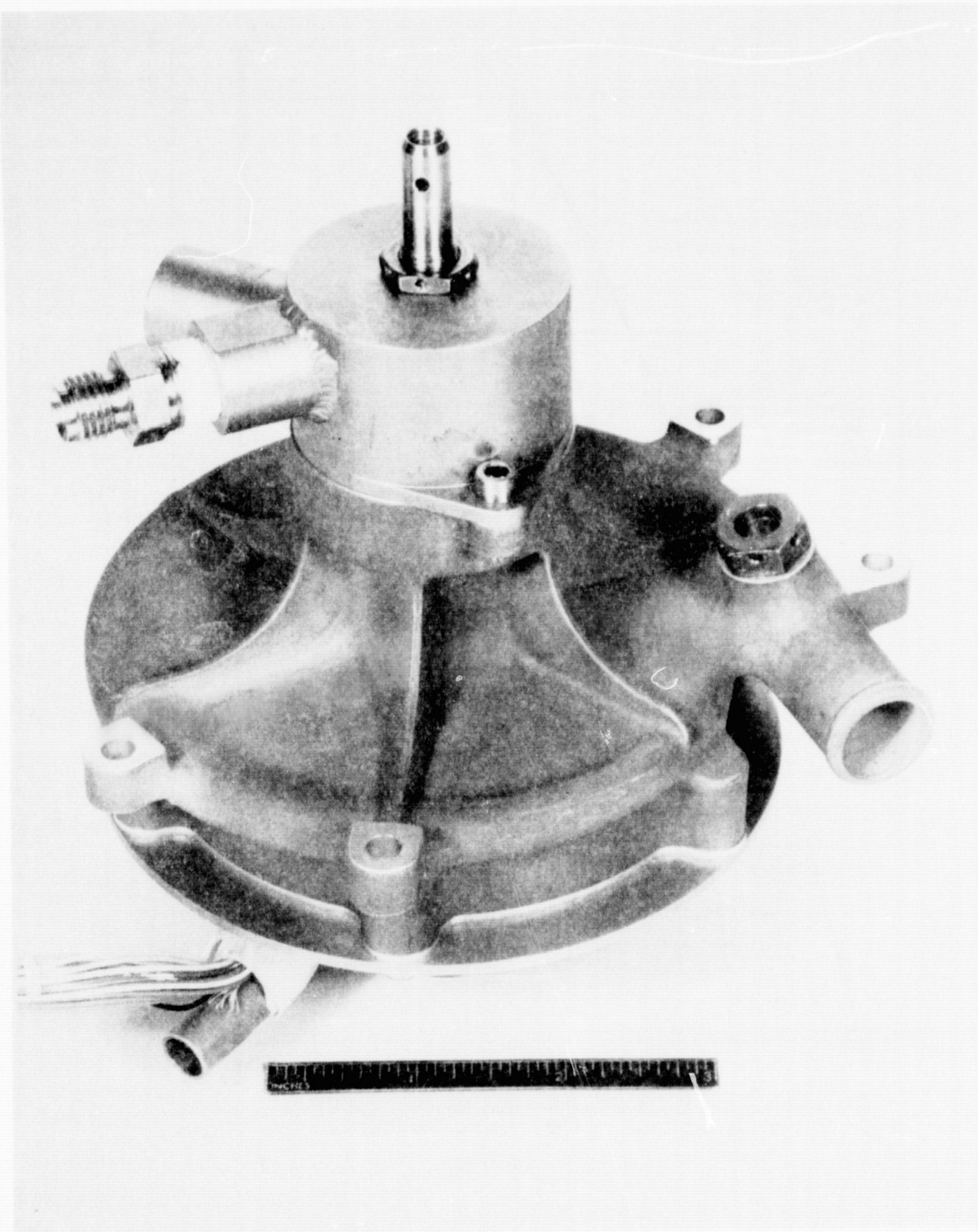
HCS Leakage

The gas loop was pressurized to 27.6 KPa (4.0 psig), and the unit was submerged in water for 15 minutes. The unit was found to have a small leak at a point in the weld between the vent loop inlet tube and the separator housing. This leak was repaired using epoxy (EC-2216), and the leakage test was repeated with no further evidence of leakage.

The liquid circuit was maintained at a pressure of 249 KPa (36 psig), and the unit was submerged in water for 15 minutes with no evidence of leakage.

HCS Fan Performance

The fan motor was adjusted to meet the design flow of 3.06 x $10^{-3} M^3$/sec (6.5 ACFM) and a pressure rise of 1.045 KPa (4.2 in H_2O) at an operating pressure of 27.6 KPa (4.0 psig) and a voltage of 16.2 volts. The fan was then operated with various flows at inlet pressures of 27.6 KPa (4.0 psia), 101.4 KPa (14.7 psia), and 129 KPa (18.7 psia). The results are included in Figure 4-4-17.



FAN SEPARATOR ASSEMBLY

FIGURE 4-4-16

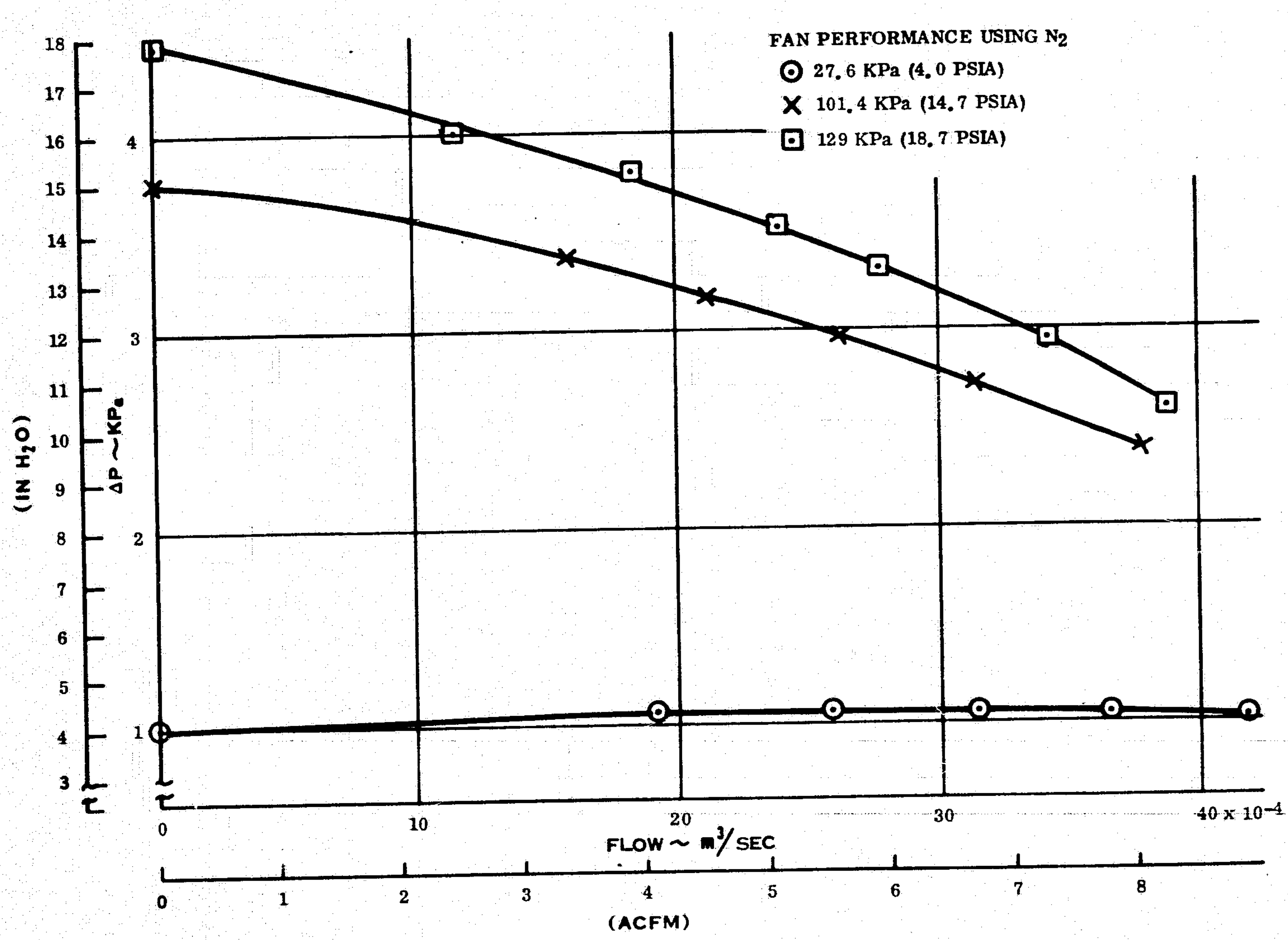


FIGURE 4-4-17

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4.4.2 (Continued)

HCS Separator Performance

Separator performance was evaluated at both 27.6 KPa (4 psia) and 129 KPa (18.7 psia). In each case, the main gas flow was set at typical operating values, and the water flow was increased from no flow to 3.6 Kg/hr (7.9 lb/hr) in 0.6 Kg/hr (1.3 lb/hr) increments. At an operating pressure of 27.6 KPa (4 psia), there was no change in speed and only a 1.3-watt increase in power consumption. At 129 KPa (18.7 psia), there was a light drop in speed (less than 20.9 rad/sec (200 rpm)) and only a .7-watt increase in power consumption. There was no gas inclusion in the outlet water when the back pressure on the pitot was maintained above 27.6 KPa (4 psia). When operating at 27.6 KPa (4 psia), the separator head generated exceeded 69 KPa (10 psig) while at 129 KPa (18.7 psia) the head exceeded 41.4 KPa (6 psig). The change in head was due to the decrease in speed at the higher operating pressure. It was determined that the pressure drop of the back pressure valve, at high water flows, exceeded the separator head produced when operating at 129 KPa (18.7 psia); however, at the expected maximum water flow of 1.8 Kg/hr (3.96 lb/hr), the head generated by the fan separator exceeded the pressure drop of the back pressure valve; therefore, the selected valve is acceptable for use in the TCS.

HCS Mission Test

The inlet pressure was set at 129 KPa (18.7 psia), and flow was set at 2.4×10^{-3} M^3/sec (5.1 ACFM). A separator inlet gas flow of $.99 \times 10^{-4}$ M^3/sec (.21 ACFM) and an inlet water flow of 2.4 Kg/hr (5.2 lb/hr) were established. The inlet pressure was then decreased to 27.6 KPa (4.0 psig), the gas flow was set at 3.06×10^{-3} M^3/sec (6.5 ACFM), and the separator gas inlet flow was increased to 1.5×10^{-4} M^3/sec (.31 ACFM). These conditions were maintained for four hours demonstrating acceptability for mission use. There was no carry over or other effects resulting from the change in operating conditions during the mission test.

HCS Off Design Test

The fan inlet pressure was set at 27.6 KPa (4.0 psi) and a flow of 3.1×10^{-3} M^3/sec (6.5 ACFM) was established. A separator water inlet flow of .6 Kg/hr (1.3 lb/hr) was established and the separator outlet was shut off. The separator outlet pressure increased to 176 KPa (25.5 psig) at which point carry over was observed in the fan outlet. The water flow was continued and the effects were observed. The speed decreased approximately 20.9 rad/sec (200 RPM) resulting in a decrease in the fan head from 1.04 KPa (4.2 in H_2O) to 1.03 KPa (4.15 in H_2O). There was a 3.5-watt increase in power due to the water passing through the fan. The unit had stabilized at these conditions until the gas circuit of the rig started filling with water at which point the test was terminated.

4.4.3 Water Transport Subsystem Fabrication and Development Test

The WTS consists of a GFE pump, a GFE water diverter valve, a gas separator, and a vehicle umbilical connector. There was no fabrication or test activity on the GFE hardware.

Gas Separator

The detail parts of the gas separator were assembled per SVSK 90475 (Figure 4-4-18), and the following tests were performed.

Examination of Product

The unit complied with the requirements of the assembly drawing. A small dent, which would have no effect on the function of the unit, was noted on the exterior of the housing.

Proof Pressure

The unit was pressurized to 379 KPa (55 psig) for five minutes with no evidence of deformation.

Leakage

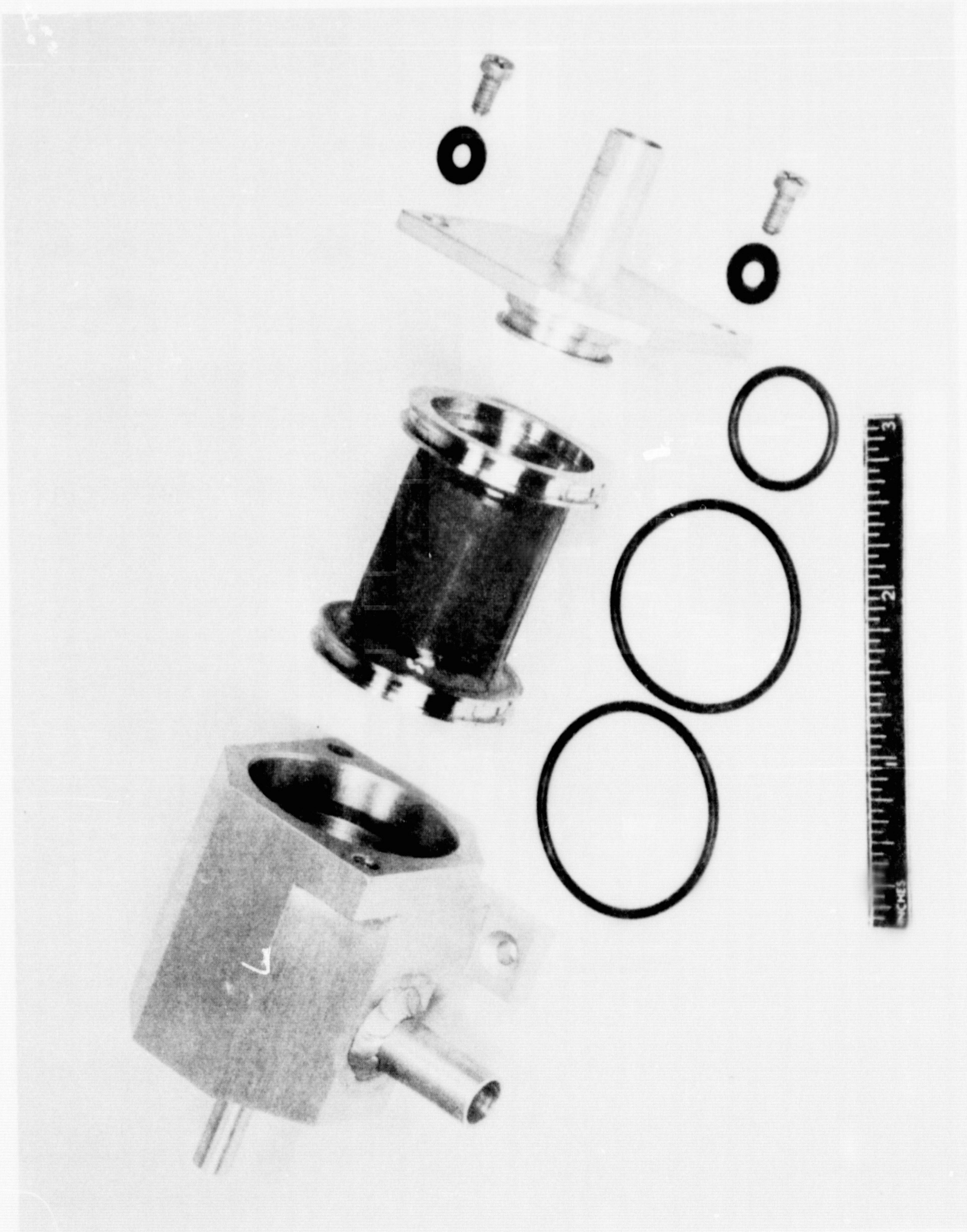
The unit was pressurized to 242 KPa (35 psig) with nitrogen and was submerged in water for five minutes. There was no evidence of leakage.

Separation Verification Test

The unit was installed in the test rig and charged with water. One and one half hour after charging, flow was initiated, and the first set of data was recorded. The performance was monitored every hour for the first seven hours and, thereafter, twice every twenty four hours for a total of one hundred and two hours of operation. The data is summarized in Table 4-4-3. The lower delta P value was recorded when water was flowing through the separator, while the higher delta P was recorded while air was being introduced to the separator at a rate of 35 cc/min. There was no gas carry-over to the outlet of the separator. At the initiation and completion of the test, air was introduced at a rate of 360 cc/min ($\sim$10 times required rate) with no evidence of gas carry-over.

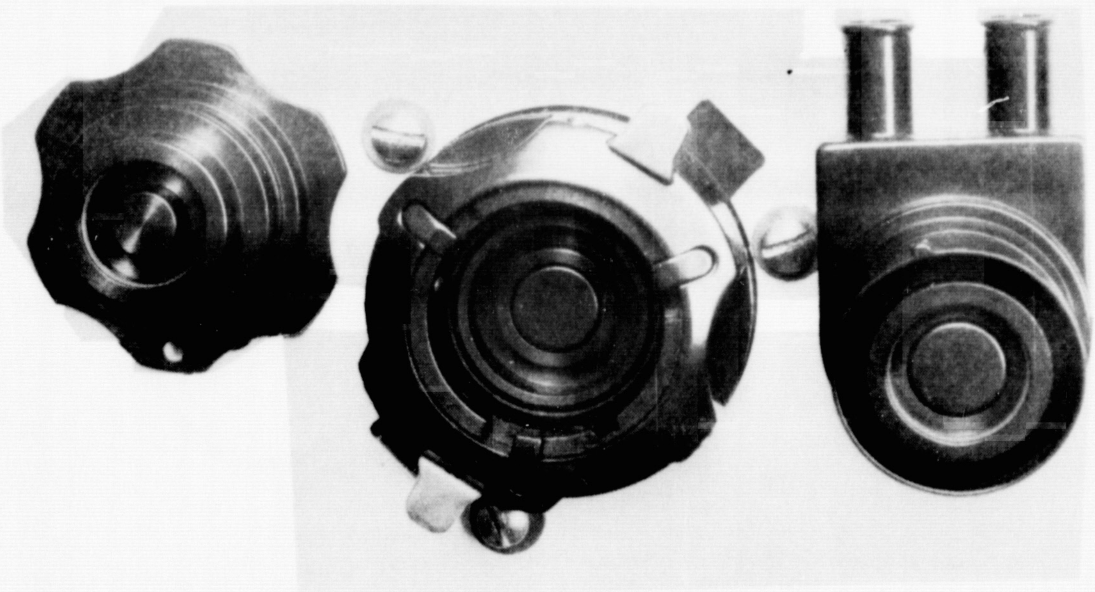
Vehicle Umbilical Connector

The vehicle umbilical connector was designed, fabricated, and assembled by the manufacturer of the Apollo PLSS multiple water connector. The unit (Figure 4-4-19) was subjected to the following test series.



GAS SEPARATOR

FIGURE 4-4-18



VEHICLE UMBILICAL CONNECTOR

FIGURE 4-4-19

TABLE 4-4-3
SEPARATION PERFORMANCE TEST RESULTS

Time Hours	Water Flow Kg/Min (lb/min)	Delta P KPa (in H_2O)	Remarks (See Note)
0	1.86 (4.1)	1.05 (4.25)	A
0		1.18 (4.75)	B
1		1.02 (4.13)	A
2		1.01 (4.06)	A
3		.99 (4)	A
4		.99 (4)	A
5		.99 (4)	A
5		1.24 (5)	B
6		.99 (4)	A
7		.962 (3.88)	A
24		.99 (4)	A
24		1.24 (5)	B
30		.99 (4)	A
30	1.86 (4.1)	1.49 (6)	B

TABLE 4-4-3
(Continued)

Time Hours	Water Flow Kg/Min (lb/min)	Delta P KPa (in H_2O)	Remarks (See Note)
46	1.86 (4.1)	.99 (4)	A
46		1.24 (5)	B
54		.99 (4)	A
54		1.36 (5.5)	B
70		1.02 (4.13)	A
70		1.36 (5.5)	B
78		1.02 (4.13)	A
78		1.36 (5.5)	B
86		1.01 (4.07)	A
86		1.12 (4.5)	B
102		1.01 (4.07)	A
102	1.86 (4.1)	1.12 (4.5)	B

Note: A = No gas in separator
B = Separating gas

4.4.3 (Continued)

Examination of Product

There was no significant visual defects noted.

Proof Pressure

The connector was subjected to a pressure of 393 KPa (57 psig) for five minutes both coupled and uncoupled. There was no evidence of deformation.

Cross Leakage

The connectors were coupled and the inlet side pressurized with water to 34.5 KPa (5 psig). There was no leakage from the inlet to outlet side of the connector.

External Leakage

The connector halves were pressurized with water to 34.5 KPa (5 psig) for 20 minutes coupled and for 20 minutes uncoupled. There was no evidence of leakage.

Force to Connect

The connector halves were pressurized to 172 KPa (25 psig) and were then coupled. The force to connect was 51.2 newtons (11.5 lbs) versus a requirement of 89 newtons (20 lbs).

Pressure Drop (Connected)

The connector halves were coupled, and the inlet and outlet of the vehicle half were connected. The water flow through the coupled pair was varied, and the pressure drop was recorded. The test results are shown in Figure 4-4-20. The unit complied with the maximum allowable pressure drop.

Pressure Drop (Uncoupled)

The connector halves were uncoupled and the pressure drop vs water flow through the backpack half was recorded. The results are shown in Figure 4-4-21. The pressure drop was significantly above the targeted value of .54 KPa (.25 psi) at a flow of 1.09 kg/hr (240 lb/hr). The higher pressure drop will have no effect on TCS performance since the pressure rise of the pump exceeds the expected total system pressure drop at 1.09 kg/hr (240 lb/hr) even considering the connectors high pressure drop.

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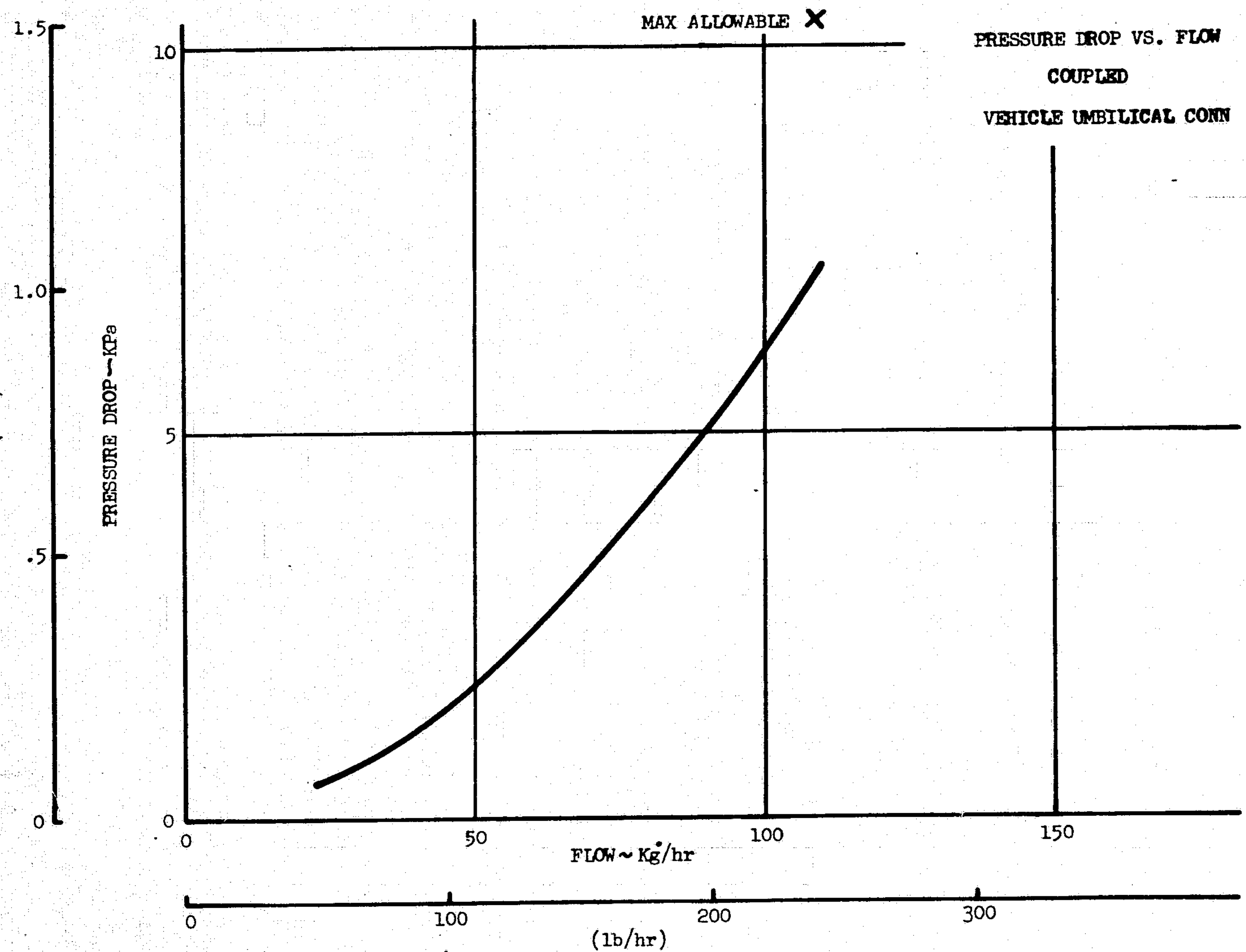


FIGURE 4-4-20

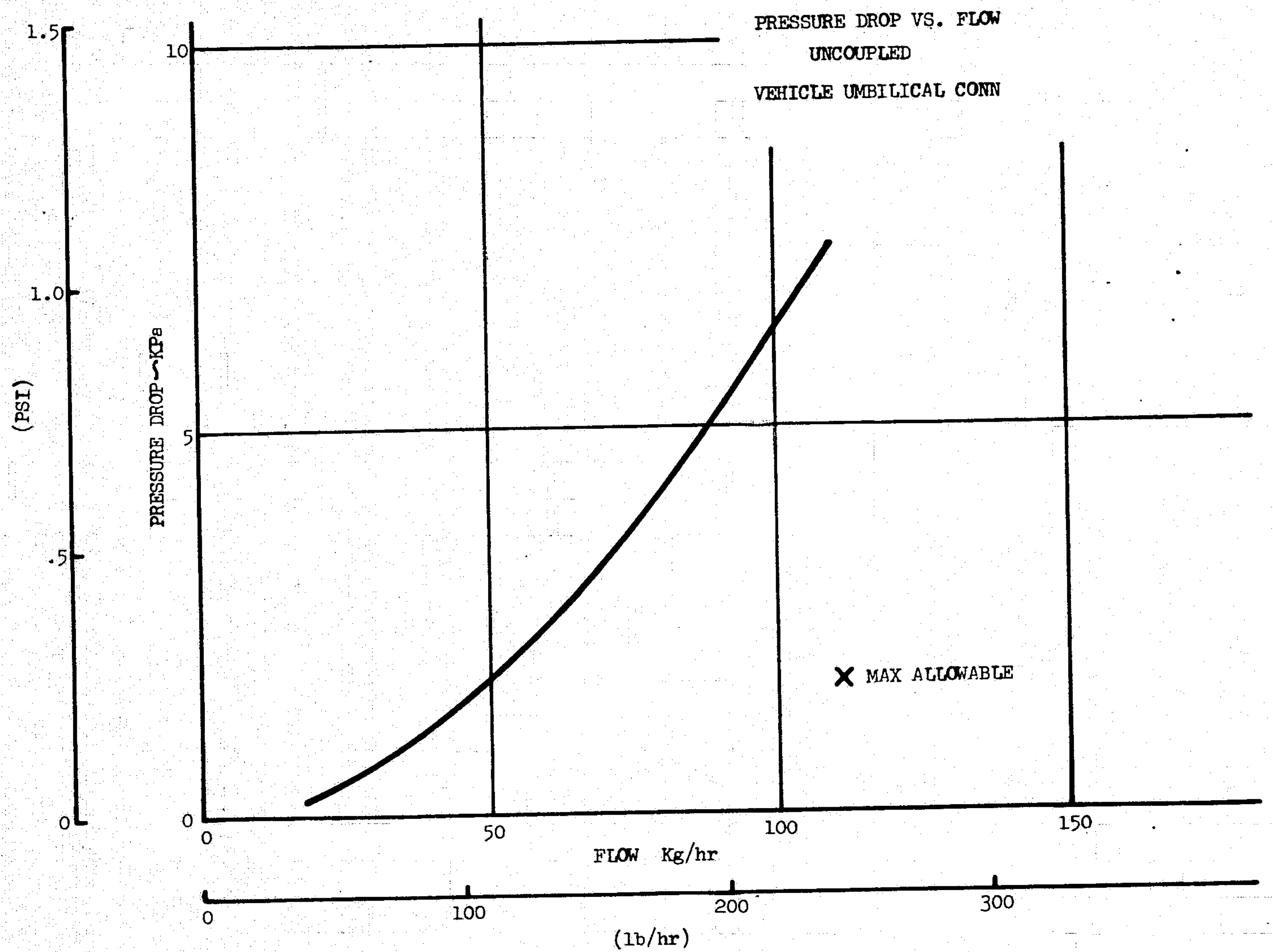

PRESSURE DROP VS. FLOW
UNCOUPLED
VEHICLE UMBILICAL CONN
PRESSURE DROP ~ KPa
(PSI)
1.5
1.0
.5
0
10
5
0
0
50
100
150
FLOW Kg/hr
0
100
200
300
(lb/hr)
X MAX ALLOWABLE

FIGURE 4-4-21

4.4.3 (Continued)

This valve was designed primarily to determine if the PLSS water connector design could be successfuly adopted for use as the vehicle umbilical water connector. The results of this test demonstrate the inherently high pressure drop of the connector which can only be resolved by increasing the size of the flow passages and minimizing turns within the connector or by utilizing a totally new design concept.

4.4.4 Water Management Subsystem Fabrication and Development Tests

The WMS consists of a reworked Apollo PLSS auxiliary water tank, an Apollo canister reservoir assembly, and various valve fittings and connectors arranged in a configuration to support the TCS requirements. These items were mounted to the TCS enclosure, and the interconnecting plumbing was installed. The assembled subsystem (Figure 4-4-22) was subjected to the following test program.

WMS Examination of Product

There were no significant visual defects noted, and the unit was found to comply with the engineering definition of the as built configuration. The dry weight was 19.94 Kg (43.86 lb).

WMS Proof Pressure

The gas circuit was pressurized to 41.6 KPa (6.04 $\pm$ .01 psig) for six minutes with no visible deformation. The liquid circuit was pressurized to 379 KPa (55 psig) for five minutes with no evidence of deformation.

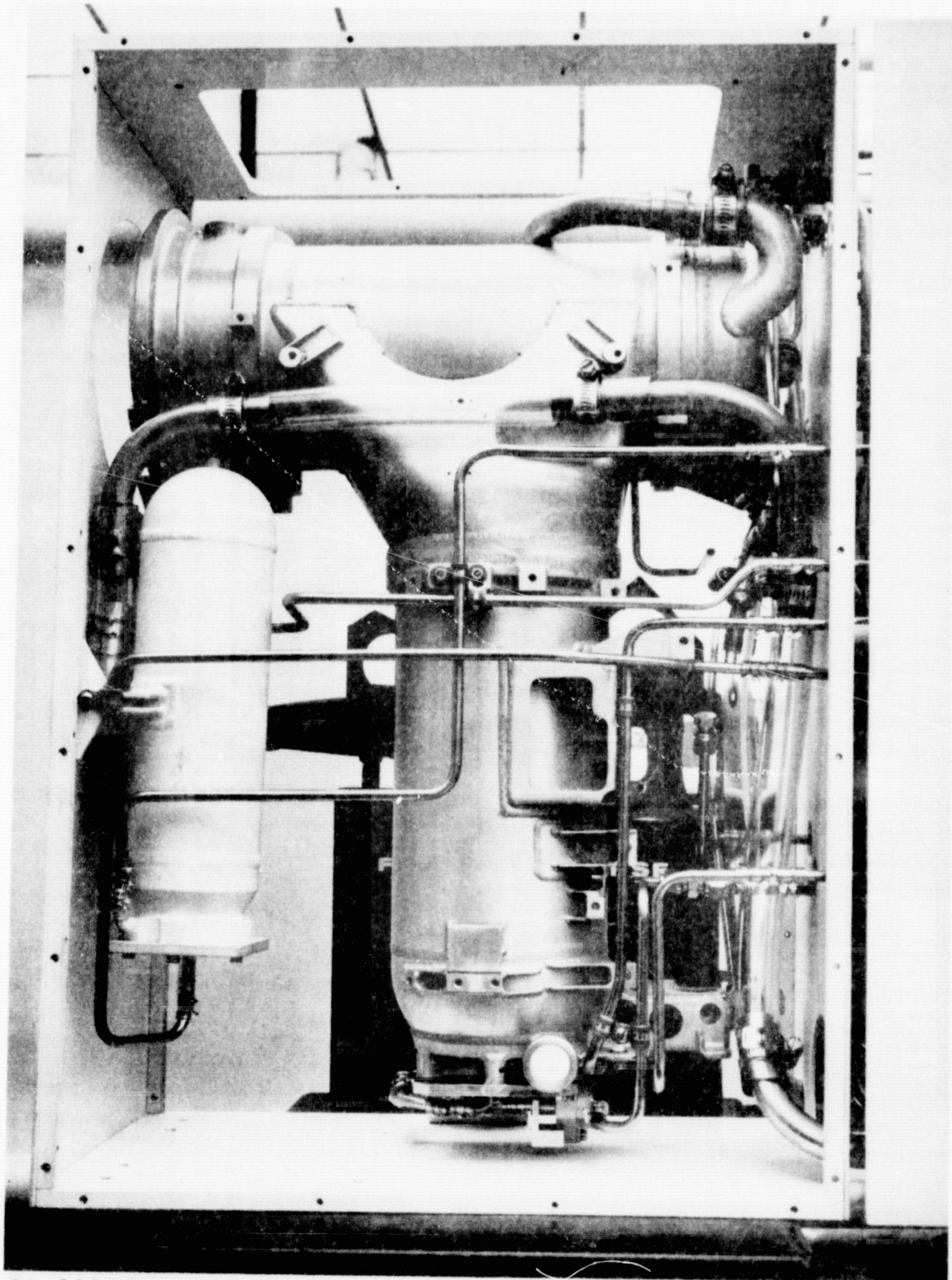
WMS Leakage

The gas loop was pressurized to 28.5 KPa (4.13 psig) and maintained at this pressure for 30 minutes. The gas inlet flow required to maintain this pressure was less than 2 cc/min vs a requirement of 18 cc/min maximum.

The liquid circuit was maintained at a pressure of 252 KPa (36.5 psig) for 15 minutes with no evidence of visual leakage.

WMS Check Valve Performance

The pressure on the upstream side of the check valve was increased until water flowed freely from the LCG bypass fitting and was then decreased until the flow stopped. The water flowed freely at an upstream pressure of 186.6 Pa (.75 in H_2O) and stopped flowing with an upstream pressure of 124.4 Pa (.5 in H_2O). This complies with the requirement that the unit must flow freely at a pressure of 6.89 KPa (1 psi).



SS 11525-4

WATER MANAGEMENT SUBSYSTEM

FIGURE 4-4-22

4.4.4 (Continued)

Main Relief Valve Performance

The main relief valve was flow cycled three times with the following results:

	Cycle 1	Cycle 2	Cycle 3
Pressure at which flow started	342.3 KPa (49.65 psig)	338.8 KPa (49.15 psig)	338.8 KPa (49.15 psig)
Pressure at which flow stopped	331.9 KPa (48.15 psig)	331.9 KPa (48.15 psig)	331.9 KPa (48.15 psig)

The valve cracking and reseat was within the test limits of 275.8 KPa (40 psig) to 344.7 KPa (50 psig).

WMS Expansion Tank Relief Valve Performance

The expansion tank relief valve was flow cycled three times with the following results:

	Cycle 1	Cycle 2	Cycle 3
Pressure at which flow started	362.9 KPa (52.65 psig)	365 KPa (52.95 psig)	364 KPa (52.85 psig)
Pressure at which flow stopped	359.5 KPa (52.15 psig)	360.2 KPa (52.25 psig)	360.2 KPa (52.25 psig)

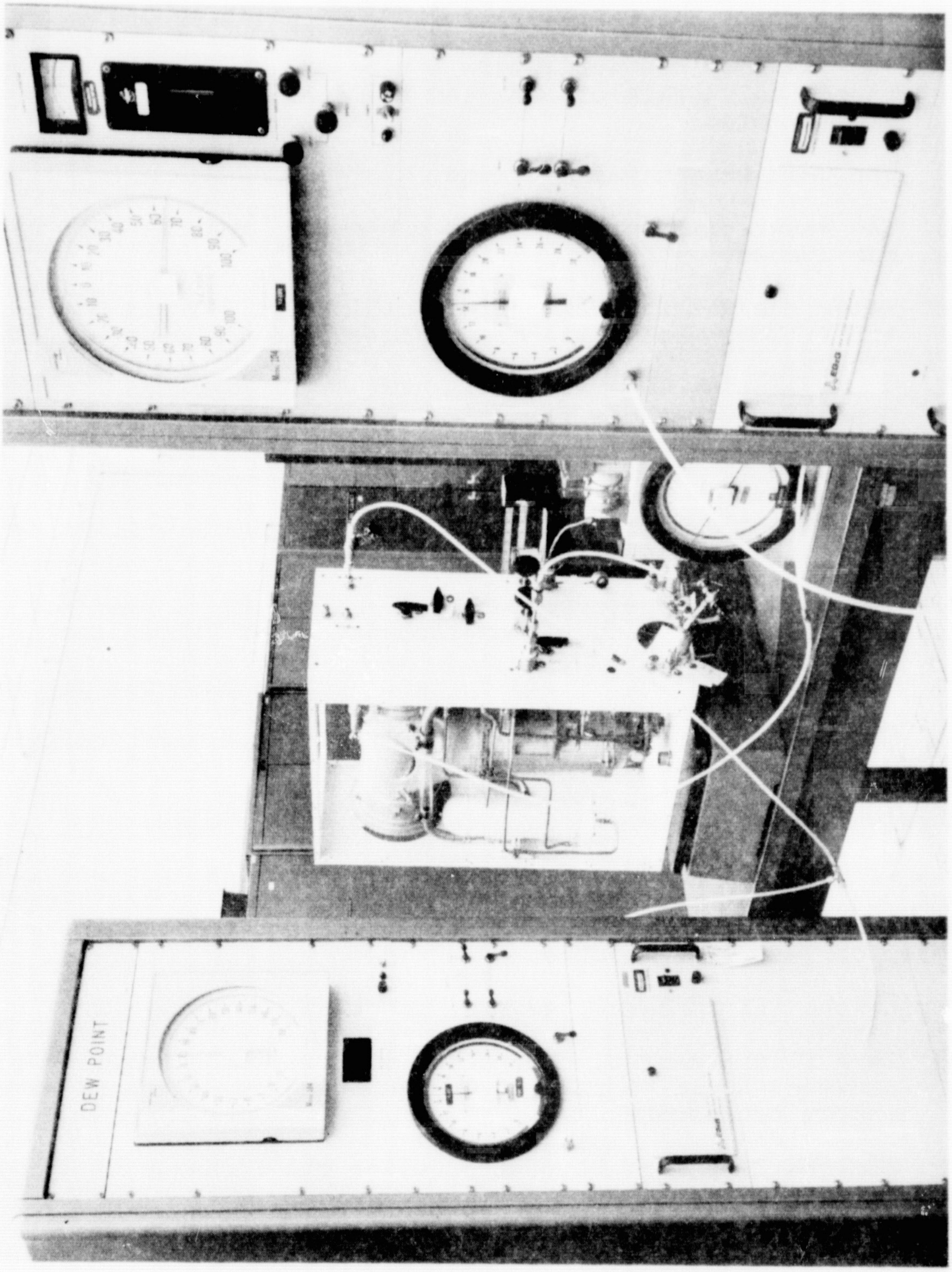
These valves exceed the test plan target of 275.8 KPa (40 psig) to 344.7 KPa (50 psig), however, since the valve met the Work Statement intent of over pressure protection, it was not readjusted.

WMS Mission Treating Venting

The mission testing was conducted to verify that the WMS would store at least 3.73 Kg (8.2 lbs) of water of which at least 3.55 Kg (7.8 lbs) was useable and that the recharge could be completed in five minutes. This test also permitted an assessment of the recharge procedure. Figure 4-4-23 shows the setup used for the mission test. The basic recharge procedure utilized was as follows:

A) The feed water shutoff valve and dump valve were closed (unless already closed).

B) The expansion tank shutoff valve was opened, and the drain fitting was connected.



WMS TEST SET UP

FIGURE 4-4-23

SS 11524-4

4.4.4 (Continued)

C) The gas loop was pressurized to 27.58 KPa (4 psig) and held until water stopped flowing from the drain connector.

D) The gas loop pressurization source and the expansion tank shuoff valve were closed, and the drain connector was disconnected.

E) The unit weight was recorded.

F) The water fill connector was connected, and the dump valve was opened.

G) After the water pressure restabilized at 248 KPa (36 psia), the fill connector was disconnected and the dump valve was closed.

H) The unit weight was recorded.

The unit was then discharged as follows:

A) The expansion tank shutoff valve was opened, and the water pressure was stabilized and recorded.

B) The vent loop pressure was decreased to 27.58 KPa (4.0 psia), and the water pressure was recorded after stabilization.

C) The feed water valve was opened, and the unit was discharged.

D) The unit weight and the weight of the feed water collected were recorded.

This cycle was repeated for a total of five cycles.

The weights and pressures recorded are included in Table 4-4-4 and verify that the WMS complies with the mission test (venting) performance requirements. The time required to charge the reservoir was four minutes.

During the test program, several observations were made.

A) In a flight design, the number of activities required of the crewmen should be reduced by combining functions of valves and/or connectors.

B) The gas loop must be vented during the recharge or it will be over pressurized.

TABLE 4-4-4

WMS VENTING MISSION TEST RESULTS - FIRST RUN

Cycle	Unit Weight Before Charge Kg (lb)	Unit Weight After Charge Kg (lb)	Unit Weight After Discharge Kg (lb)	Weight of Water Added Kg (lb)	Weight of Water Removed Kg (lb)	Weight of Water Collected Kg (lb)	Water Pressure: After Charge KPa (psia)	Water Pressure: After Expansion Tank Shutoff Valve Opened KPa (psia)	Water Pressure: With Vent Loop at KPa (4.0 psia) KPa (psia)
1	20.42 (44.92)	24.43 (53.75)	20.48 (45.06)	4.01 (8.83)	3.95 (8.69)	3.95 (8.69)	248 (36)	*See Note	
2	20.49 (45.07)	24.38 (53.63)	20.52 (45.16)	3.89 (8.56)	3.85 (8.47)	3.89 (8.56)	248 (36)	101.3 (14.7)	28.3 (4.1)
3	20.50 (45.10)	24.4 (53.68)	20.62 (45.36)	3.9 (8.58)	3.78 (8.32)	3.78 (8.32)	248 (36)	*See Note	
4	20.51 (45.12)	24.38 (53.64)	20.5 (45.09)	3.87 (8.52)	3.89 (8.55)	3.91 (8.61)	248 (36)	101.3 (14.7)	28.3 (4.1)
5	20.50 (45.09)	24.37 (53.62)	20.5 (45.11)	3.88 (8.53)	3.87 (8.51)	3.89 (8.55)	248 (36)	101.3 (14.7)	28.3 (4.1)

Note: Tests marked * run with water pressure gauge disconnected.

4.4.4 (Continued)

C) The fluid being discharged was a mixture of free gas and water throughout the discharge cycle with the quantity of air increasing near the end of the discharge cycle.

D) In runs where the water fill connector was left connected to verify the liquid loop pressure, the gas in the line forced additional water into the system from the line and gauge after the charged weight had been recorded. This additional water was removed as feed water making the feed water weight greater than the weight decrease of the system. In runs where the fill connector was not reconnected after the charged weight was recorded, the feed water collected was equal to the system weight decrease.

WMS Mission Testing Non-Venting

This test was conducted to verify that the expansion tank could hold at least .77 Kg (1.7 lbs). The expansion tank was charged with the expansion tank shutoff valve closed. The unit weight increased from 20.58 Kg (45.28 lbs) to 21.54 Kg (47.38 lbs) for a weight increase of .95 Kg (2.1 lbs) verifying compliance with the requirements.

WMS Service

The service test was conducted to determine the effectiveness of the deactivation and drying procedure.

Because of the number of fittings and water tubes, the liquid loop and feed water circuit discharge was modified to better assure removal of water from the system. The revised procedure was as follows:

A) The LCG flow control valves, the expansion tank and umbilical shutoff valves were opened, and the feed water and dump valves were closed.

B) The feed water circuit was pressurized through the fill connector to 28 KPa (4 psig) with nitrogen.

C) In turn, the LCG outlet fitting, LCG inlet fitting, umbilical outlet fitting, umbilical inlet fitting, LCG bypass fitting and LCG outlet pressure port fitting were uncapped, purged for five minutes and recapped.

D) The LCG bypass fitting was uncapped, and the unit was rotated until the control panel was facing down. This attitude was held for two minutes.

4.4.4 (Continued)

E) The unit was put right side up, and Step C was repeated except the purge time was reduced to one minute per fitting.

F) The recharge connector was removed, the drain connector was installed, and the feed water valve was opened.

G) The gas circuit was pressurized to 28 KPa (4 psig), and the slurper pressure port fitting and the gas outlet pressure port fitting were uncapped, and the unit was held with the control panel facing down for two minutes.

H) The unit was righted, and the gas supply was disconnected. This procedure appeared to remove all free water from the WMS.

For the final drying, the canister cover was removed as well as all fittings being uncapped. Also, the fill and drain connectors were left installed. After the unit was exposed to a vacuum for one hour, the chamber was returned to ambient using room air rather than dry nitrogen.

The dry out verification for each circuit was accomplished by purging with dry nitrogen and observing the outlet dew point every five minutes. When three successive readings were less than -17.8°C (0°F), the unit was considered dry. The verification was to take less than 30 minutes per circuit. The gas circuit required 23 minutes, the feed water circuit required 11 minutes, and the liquid loop required 10 minutes. The test verified the adequacy of the dry out procedure.

WMS Mission Test (Non-Venting) (Second Test)

During the second mission test in the non-venting mode, .96 Kg (2.12 lbs) of water was required for charging the bubble expansion tank.

WMS Mission Test (Venting) (Second Test)

The procedure utilized in the first mission test in the venting mode was repeated with the results summarized in Table 4-4-5. Again, the unit complied with the performance requirements.

WMS Leakage Test (Second Test)

The gas and liquid circuit leakage tests were repeated with no change from the previous leakage test results.

TABLE 4-4-5

WMS VENTING MISSION TEST RESULTS - SECOND RUN

Cycle	Unit Weight Before Charge Kg (lb)	Unit Weight After Charge Kg (lb)	Unit Weight After Discharge Kg (lb)	Weight of Water Added Kg (lb)	Weight of Water Removed Kg (lb)	Weight of Water Collected Kg (lb)	Water Pressure		
							After Charge KPa (psia)	After Expansion Tank Shutoff Valve Opened KPa (psia)	With Vent Loop at KPa (4.0 psia) KPa (psia)
1	20.4 (44.89)	24.35 (53.58)	20.49 (45.08)	3.95 (8.69)	3.86 (8.5)	3.90 (8.58)	248 (36)	101.3 (14.7)	27.8 (4.0)
2	20.49 (45.07)	24.37 (53.61)	20.5 (45.09)	3.88 (8.54)	3.87 (8.52)	3.91 (8.61)	248 (36)	101.3 (14.7)	27.8 (4.0)
3	20.5 (45.09)	24.36 (53.59)	20.5 (45.10)	3.86 (8.50)	3.86 (8.49)	3.86 (8.49)	248 (36)	See Note *	*
4	20.5 (45.10)	24.37 (53.62)	20.49 (45.07)	3.87 (8.52)	3.89 (8.55)	3.93 (8.64)	248 (36)	101.3 (14.7)	27.8 (4.0)
5	20.48 (45.05)	24.37 (53.61)	20.49 (45.08)	3.89 (8.56)	3.88 (8.53)	3.91 (8.61)	248 (36)	101.3 (14.7)	27.8 (4.0)

Note: Test marked * run with pressure gauge disconnected.

4.4.4 (Continued)

Service

The system deactivation was repeated with the dry out verification requiring 25 minutes for the gas loop, 17 minutes for the feed water circuit, and 16 minutes for the liquid circuit.

Examination of Product (Final)

There was no change from the initial examination of product except that the painted surfaces were slightly dirtier. These surfaces will be cleaned when the TCS is assembled.

4.5 System Fabrication and Development Test

Subsequent to the subsystem test programs, the subsystems were combined to form the Thermal Control System. Due to program requirement and schedule changes, this effort was conducted in two stages. In the initial stage, the HRS (sublimator), WMS (main reservoir, bubble expansion tank, valves, etc.), and the HCS (rotary separator) were combined to form the Thermal Control System shown schematically in Figure 4-5-1 and pictorially in Figure 4-5-2. The system level test program was conducted with this configuration of the TCS. After system level testing, the TCS was updated to include the WTS components. The schematic of the updated TCS configuration is shown in Figure 4-5-3. No testing was performed with the updated configuration.

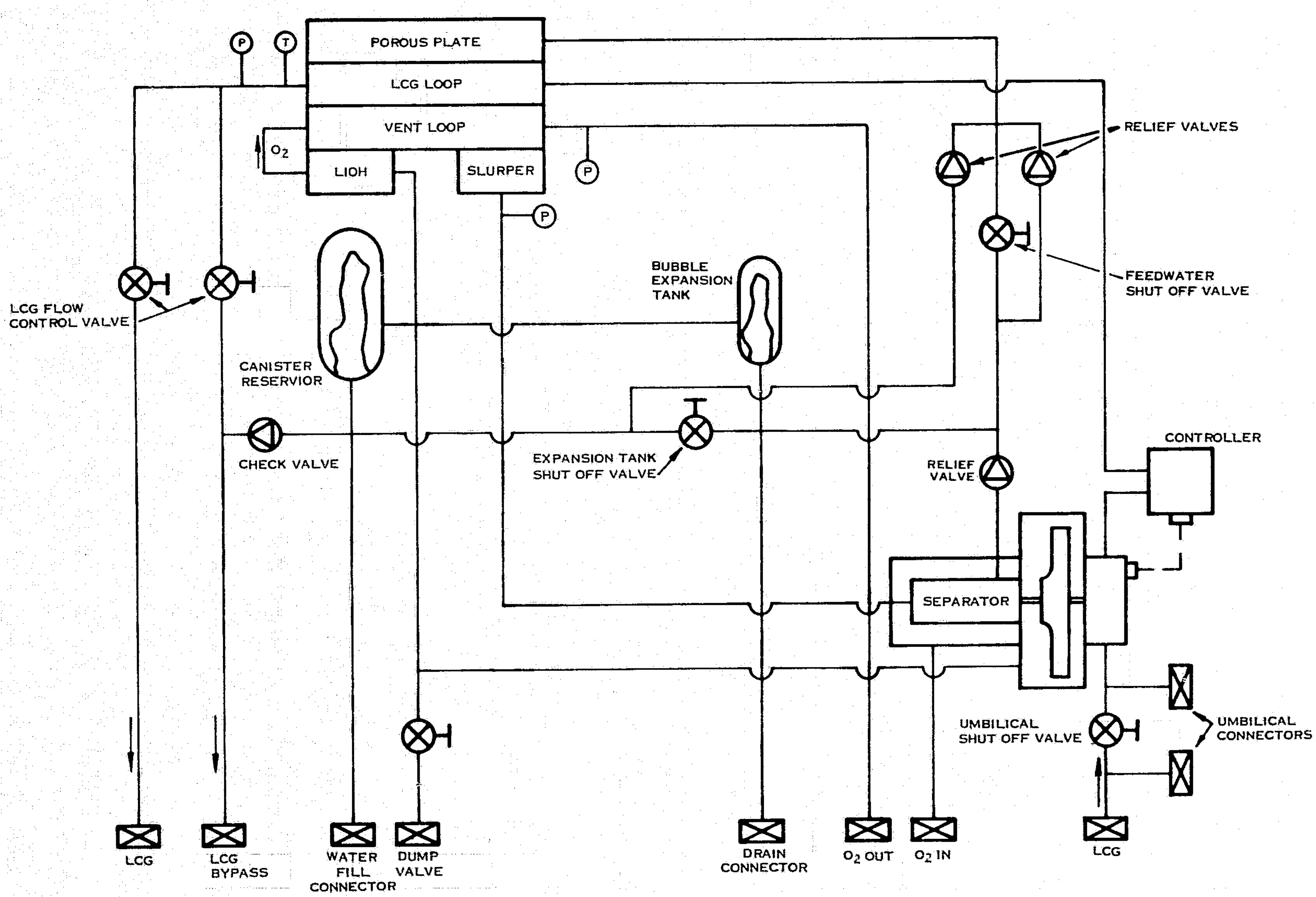
The system level test program consisted of the tests listed in Table 4-5-1.

Figure 4-5-4 presents a summary of the outlet dew point and liquid loop outlet temperatures versus total heat load. At the maximum required heat load of 909 watts (3100 Btu/hr) both the outlet dew point and liquid loop outlet temperature complied with work statement requirements. The heat load shown consists of the vent loop latent and sensible heat loads, the liquid loop load and the heat load induced by the fan/separator assembly and a heater which was utilized to prevent cooling in the canister assembly.

The test program was conducted in accordance with test plan TCS-4 and consisted of the following:

TCS Examination of product

The unit was free from visual defects and complied with the definition of the unit.



TCS SCHEMATIC

FIGURE 4-5-1

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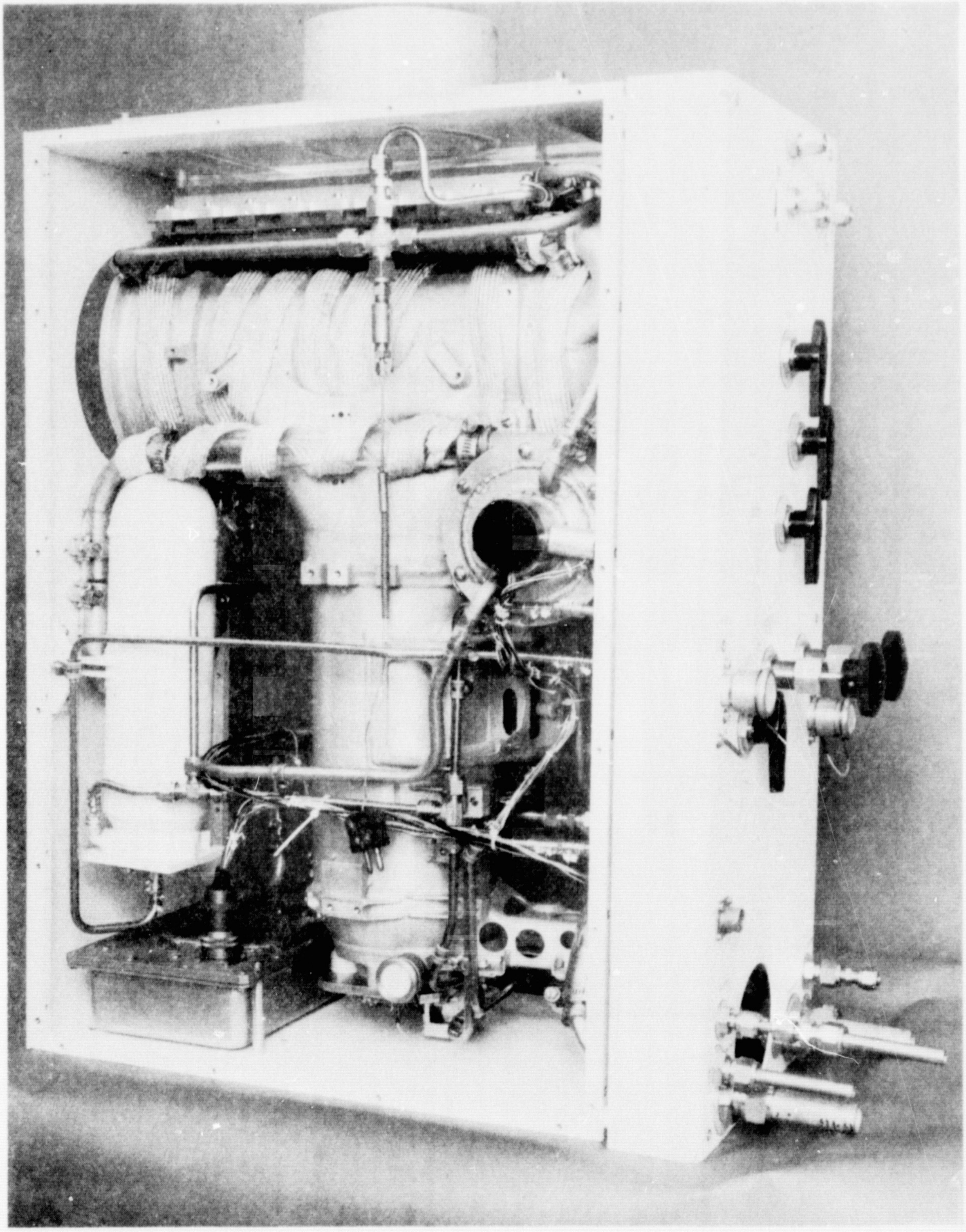
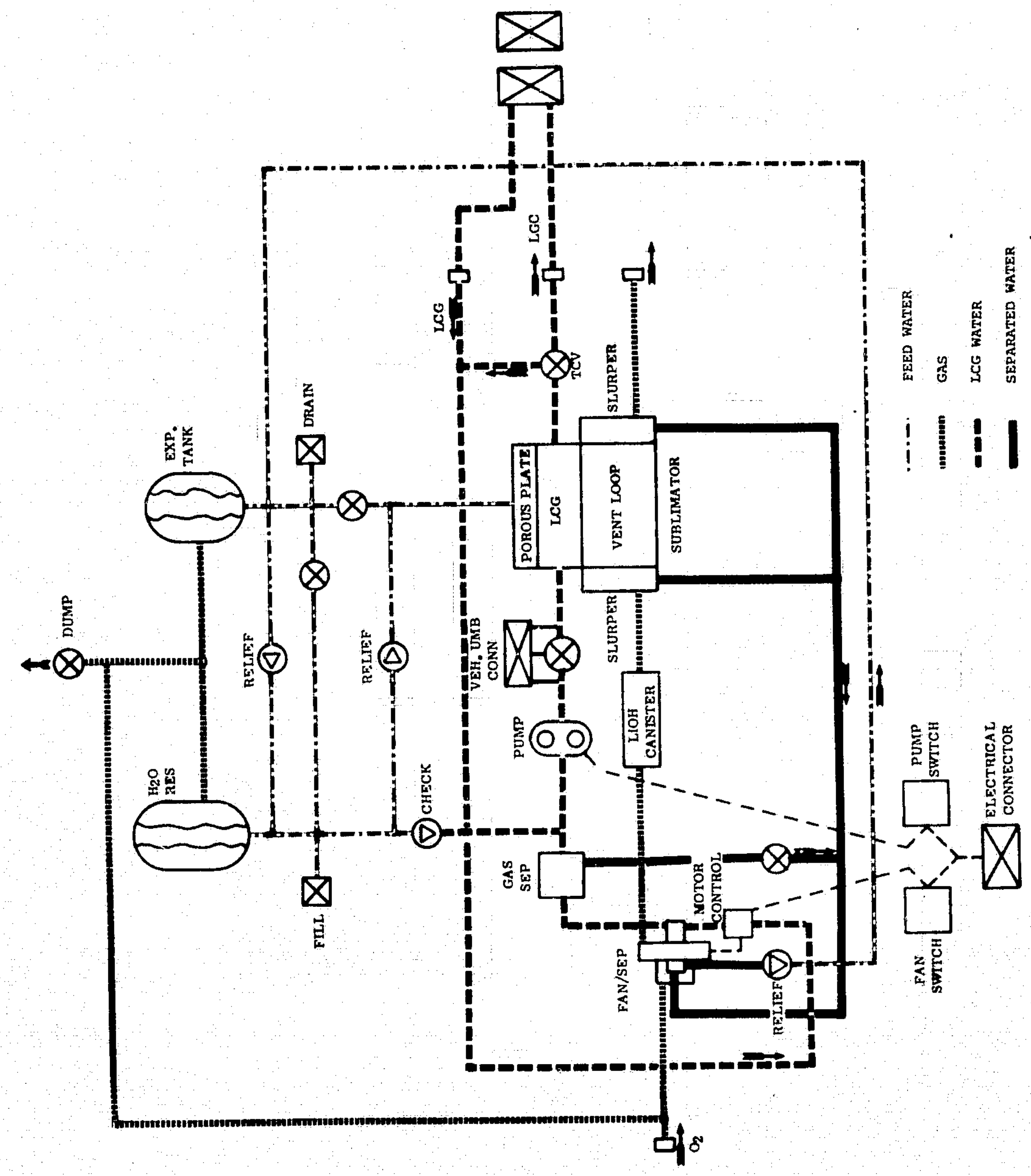


SS-11994-4 TCS TEST CONFIGURATION

FIGURE 4-5-2



FINAL CONFIGURATION

FIGURE 4-5-3

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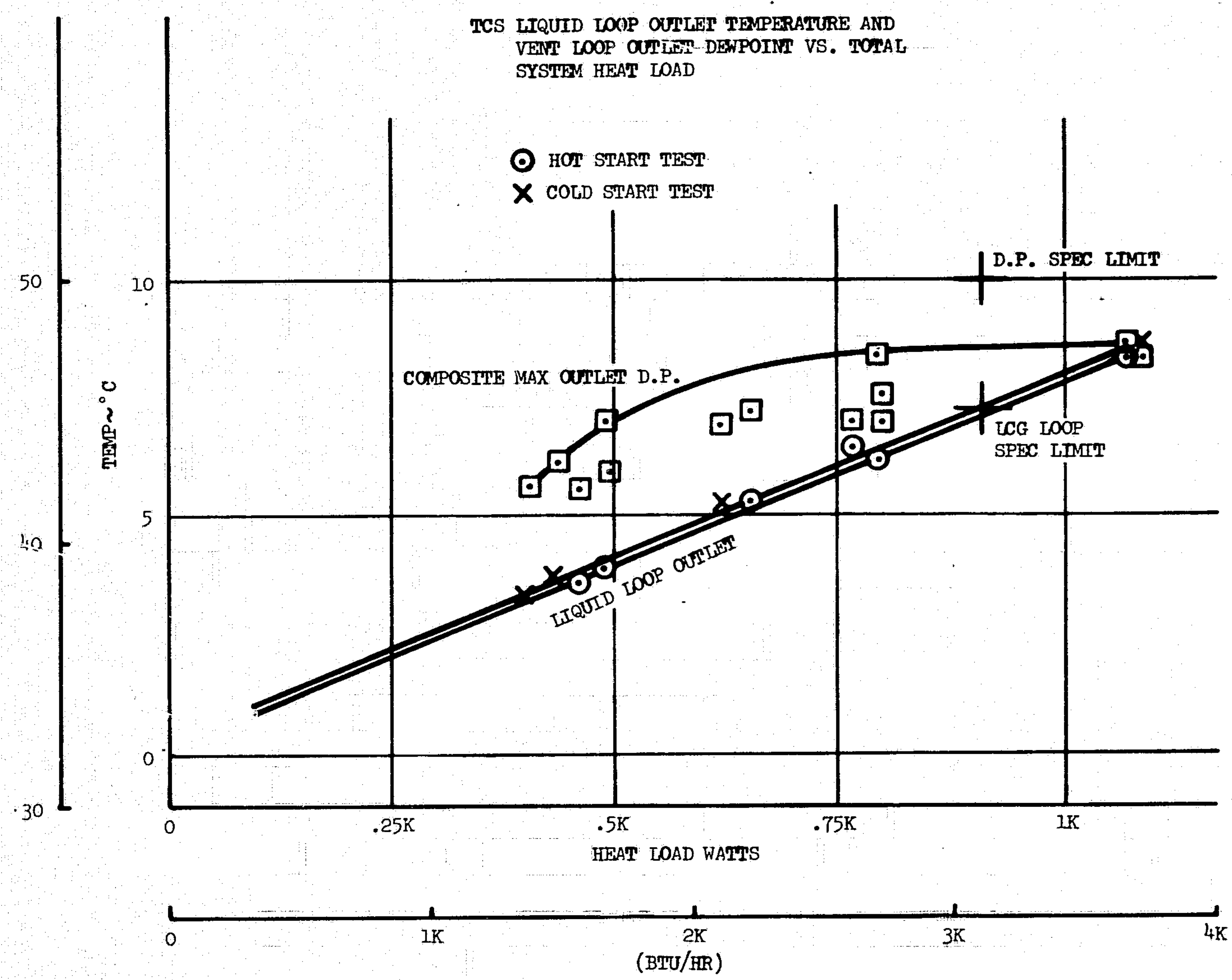

FIGURE 4-5-4

TABLE 4-5-1

TCS TEST SUMMARY

(TCS tested less WTS components, tests conducted with sublimator Number 1 and porous plate Number 2)

Test	Performance Data Location
Examination of Product	N/A
Proof Pressure	N/A
Gas Circuit Leakage	N/A
Liquid Circuit Leakage	N/A
Mission Test (Room Temp Start)	Appendix D Table D-12
Mission Test (Cold Start)	Appendix D Table D-13
Mission Test (Hot Start)	Appendix D Table D-14
System Pressure Rise vs Flow	paragraph 4.5
Umbilical Operation	paragraph 4.5
Deactivation	

4.5 (Continued)

TCS Proof Pressure

The gas circuit was pressurized with nitrogen to 42 KPa (6.1 psig) for five minutes with no evidence of deformation. The liquid circuit was pressurized with nitrogen to 379 KPa (55 psig) for five minutes with no evidence of deformation.

TCS Gas Circuit Leakage

The gas circuit was charged to 28 KPa (4.05 psig), and this pressure was maintained for 20 minutes. The flow required to maintain the pressure was 27 cc/min vs a requirement of 18 cc/min. The leakage was traced to two areas, one being the rotary separator relief valve and the second being a leak through the fan motor wire. The relief valve leakage was checked and figured to be 10cc/min at 28 KPa (4.03 psig) because this pressure was close to the cracking pressure of the relief valve. During normal operation the pressure differential between the two circuits is less than 1.4 KPa (0.2 psig). At this pressure, there was no gas leakage through the relief valve, thus the relief valve was subtracted from the flow required to maintain a constant pressure resulting in an actual external leakage of 17 cc/min which met the test requirement.

The motor used for the fan separator was a prototype unit which did not contain hermetically sealed wire terminators making it possible for gas leakage to occur between the conductor and insulator. In a flight unit design, no leakage would be expected in this area.

TCS Liquid Circuit Leakage

The liquid circuit was pressurized with water to 241 KPa (35 psig) for twenty minutes. Two leaks were detected. One leak was the previously discussed and accepted leak between the transport circuit and feed water circuit in the sublimator (reference paragraph 4.4.1). The second leak was in the weld joint between the fan motor electronics and the cooling tube. This leak was eliminated by sealing with an epoxy (Scotchweld EC 2216).

TCS Mission Test (Room Temperature Start)

The reservoir was charged to 248 KPa (36 psig) with saturated water. After the fill connector was uncoupled, the bubble expansion tank shutoff valve was opened allowing the water pressure in the reservoir to drop to room ambient pressure. The vent loop pressure was then decreased to 26.2 KPa (3.8 psia), and the liquid loop pressure dropped to 276.6 KPa (4.0 psia) confirming proper operation of the expansion tank.

4.5 (Continued)

The test chamber and steam header were evacuated, typical gas circuit and liquid circuit inlet conditions were established after which feed water flow was initiated and maintained for four hours. During this test, the gas loop and liquid loop inlet conditions were varied to approximate inlet conditions that would occur at various metabolic loads. After about 20 minutes of operation, the gas circuit pressure rise dropped significantly. It was theorized that this was caused by water condensing and collecting upstream of the sublimator because conduction to the sublimator resulted in duct wall temperatures lower than the inlet dew point. After 55 minutes of operation, the steam used to establish the gas dew point was shut off allowing the relatively dry gas to pick up the free water. As the run progressed, the gas circuit pressure rise increased as shown in Figure 4-5-5, thus confirming that the drop in head was due to water condensing in the ducts. It was concluded that a means of heating the canister and other inlet duct work should be incorporated before conducting the remaining mission tests. A summary of the performance data obtained during this test is included in Appendix D. The system complied with the Work Statement requirements.

TCS Mission Test (Cold Start)

Prior to initiation of this test, the canister and the duct between the fan and canister were wrapped with heater tape to maintain the wall temperatures above the inlet dew point. The unit was then charged with water, the vent loop and gas loop inlet conditions were established, and the feed water flow was initiated. After approximately 30 minutes of operation, it was suspected that some breakthrough was occurring because of a high liquid loop outlet temperature at a low load. The test was continued, and at 100 minutes of operation, the sublimator steam outlet header pressure increased significantly confirming the breakthrough. The unit was shut down, and the test results were evaluated. It was determined that heat conducted to the sublimator from the heater tape resulted in a high temperature at the porous plate imposing an abnormally high heat load on the plate which resulted in the breakthrough. The aluminum mounting channel and shims were replaced with parts made of Zytel 101 in order to thermally isolate the sublimator from conducted heat loads.

The test was then repeated with no evidence of breakthrough even at heat loads significantly higher than specification requirements. The gas loop pressure rise remained essentially constant during this run except for the high dew point case where it dropped slightly because the extra moisture resulted in a high flow

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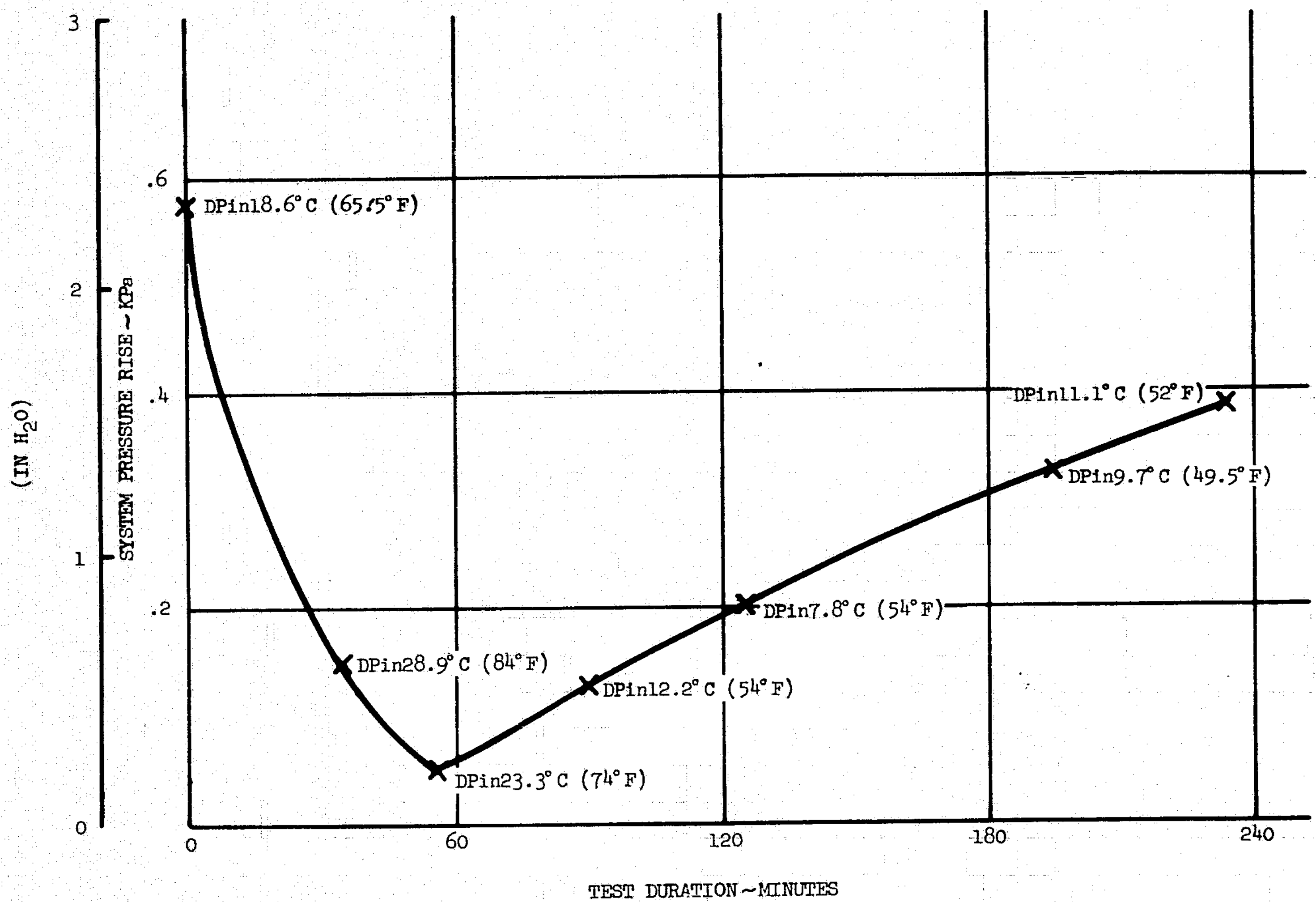

SYSTEM PRESSURE RISE VS TEST DURATION

FIGURE 4-5-5

4.5 (Continued)

rate through the systems. The results of the test are summarized in Appendix D. At the maximum specified heat load of 909 watts (3,100 Btu/hr) the outlet conditions meet specification requirements.

TCS Mission Test (Hot Start)

The system was recharged and then heat soaked to 40.6°C (105°F). The feed water flow was initiated, and performance was observed. For a few minutes after start up, there was a slight increase in the steam header pressure indicating possible breakthrough; however, the header pressure soon returned to the pre start up level and stayed there for the remainder of the run. After testing was completed, the plate area was visually examined and was free of any evidence of ice. The results of this test indicate that the unit is capable of hot start; however, because of the possibility that some breakthrough occurred during the start up, a flow limiting orifice should be incorporated in the feed water line.

As with the previous mission tests, the inlet conditions were varied to typical metabolic levels. The data from this run is summarized in Appendix D. Once again, the performance was in accordance with requirements.

TCS System Pressure Rise vs Flow

The pressure rise for the TCS was obtained at various flows at gas inlet pressures of 25.5 KPa (3.7 psia), 101.4 KPa (14.7 psia), and 129 KPa (18.7 psia) for engineering information. The results of this test are included in Figure 4-5-6.

TCS Umbilical Operation

The performance of the system at conditions simulating umbilical operation was obtained for engineering information. The test was conducted at inlet pressures of 26.9 KPa (3.9 psia), 102.3 KPa (14.8 psig), and 129 KPa (18.7 psia). During this test, the liquid loop and gas loop inlet temperatures were maintained at constant levels, and the inlet dew point was varied to simulate changes in metabolic load. The results of this test are summarized in Figures 4-5-7 through 4-5-9.

TCS Deactivation

After completion of the performance tests, any water in the feed water and liquid loops was discharged, and gas circuit was purged with dry nitrogen for one hour. The unit was then subjected to three one hour vacuum exposures with all fittings and valves open to remove any residual water. The adequacy of the dry out cycle

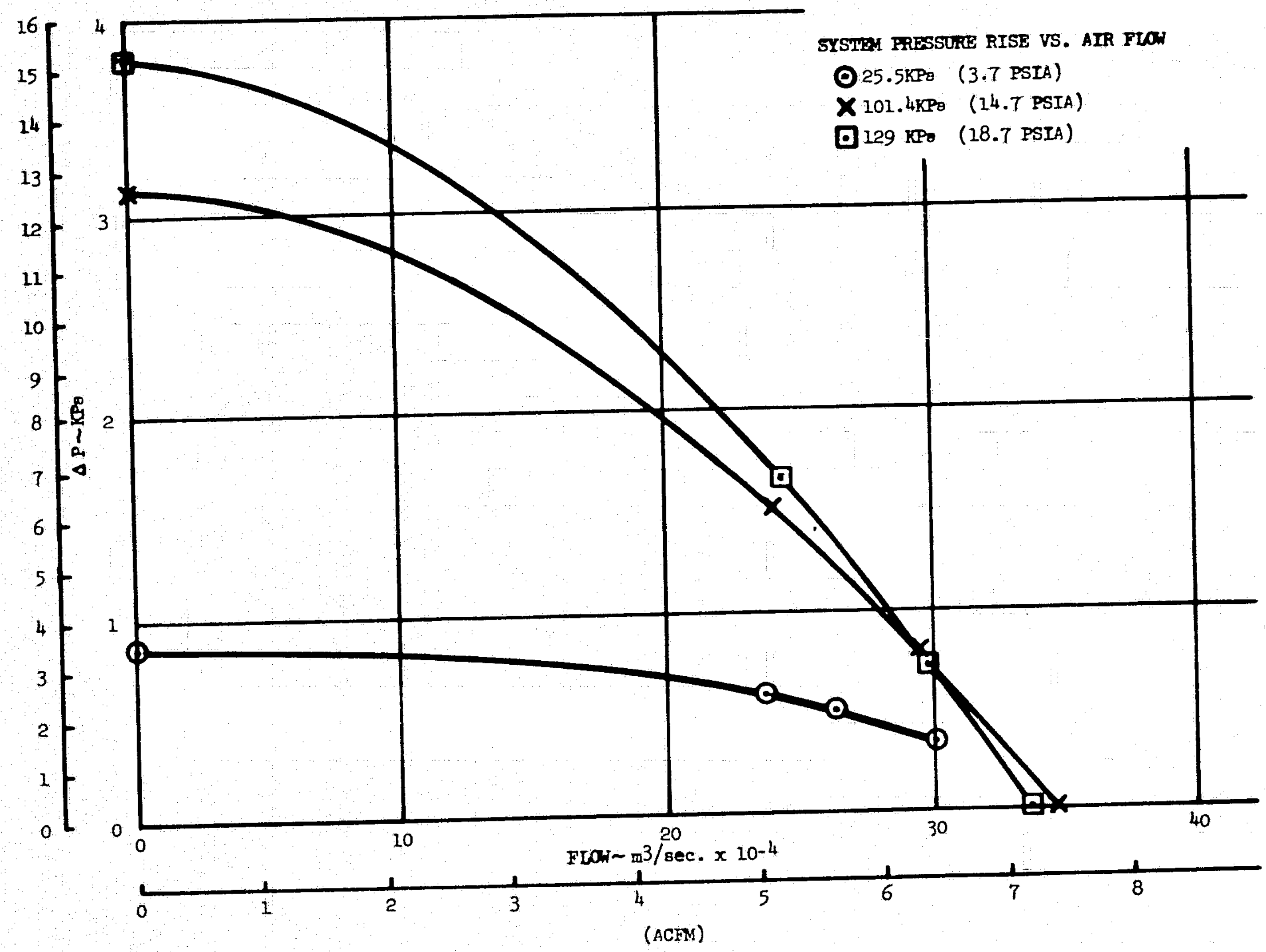
SYSTEM PRESSURE RISE VS. AIR FLOW
25.5KPa (3.7 PSIA)
101.4KPa (14.7 PSIA)
129 KPa (18.7 PSIA)
(IN H_2O)
Δ P~KPa
FLOW~ m^3/sec. x 10^{-4}
(ACFM)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
20
30
40

FIGURE 4-5-6

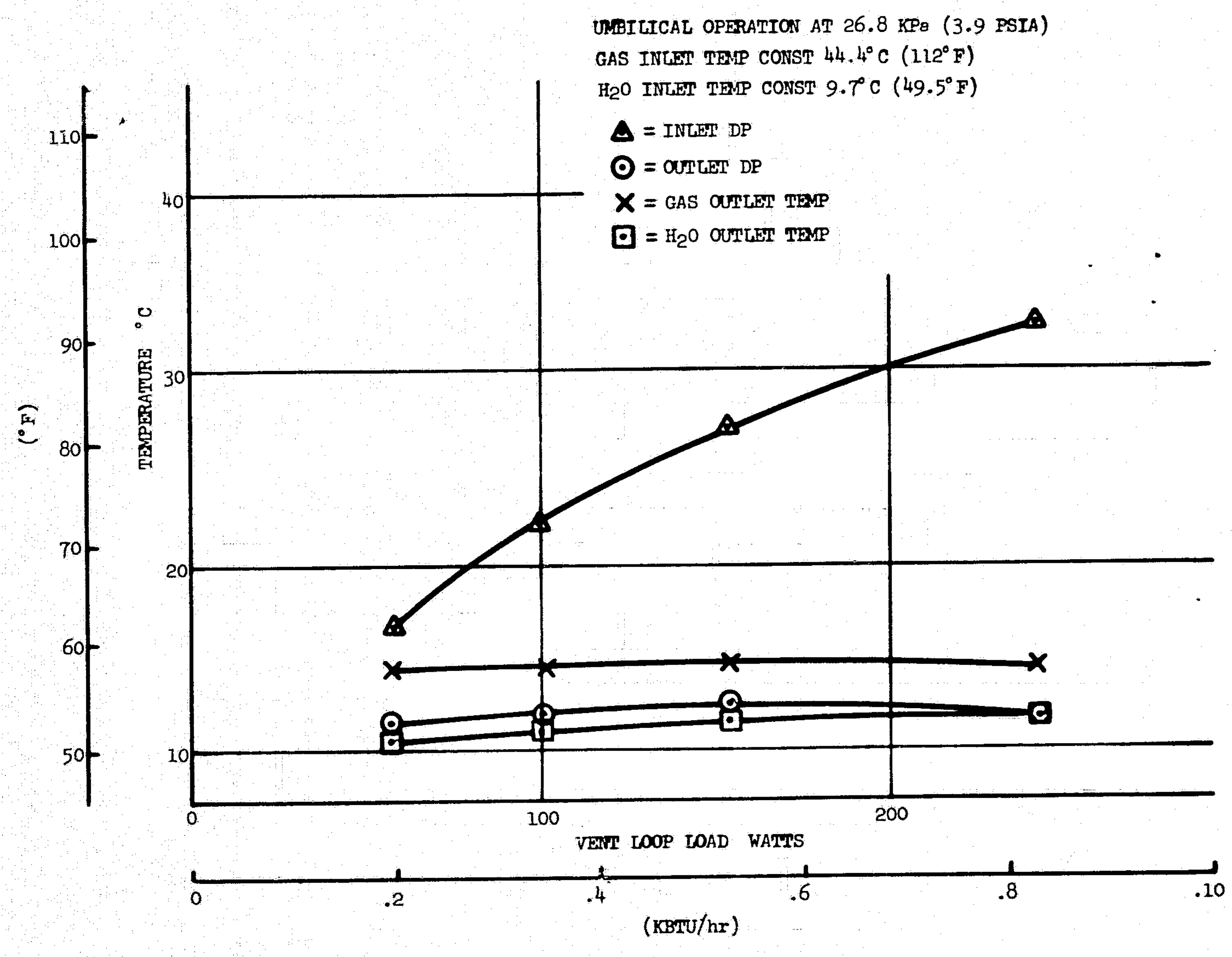
UMBILICAL OPERATION AT 26.8 KPa (3.9 PSIA)
GAS INLET TEMP CONST 44.4°C (112°F)
H2O INLET TEMP CONST 9.7°C (49.5°F)
△ = INLET DP
⊙ = OUTLET DP
X = GAS OUTLET TEMP
⊡ = H2O OUTLET TEMP
TEMPERATURE °C
(°F)
110
100
90
80
70
60
50
40
30
20
10
0
100
200
VENT LOOP LOAD WATTS
0
.2
.4
.6
.8
.10
(KBTU/hr)

FIGURE 4-5-7

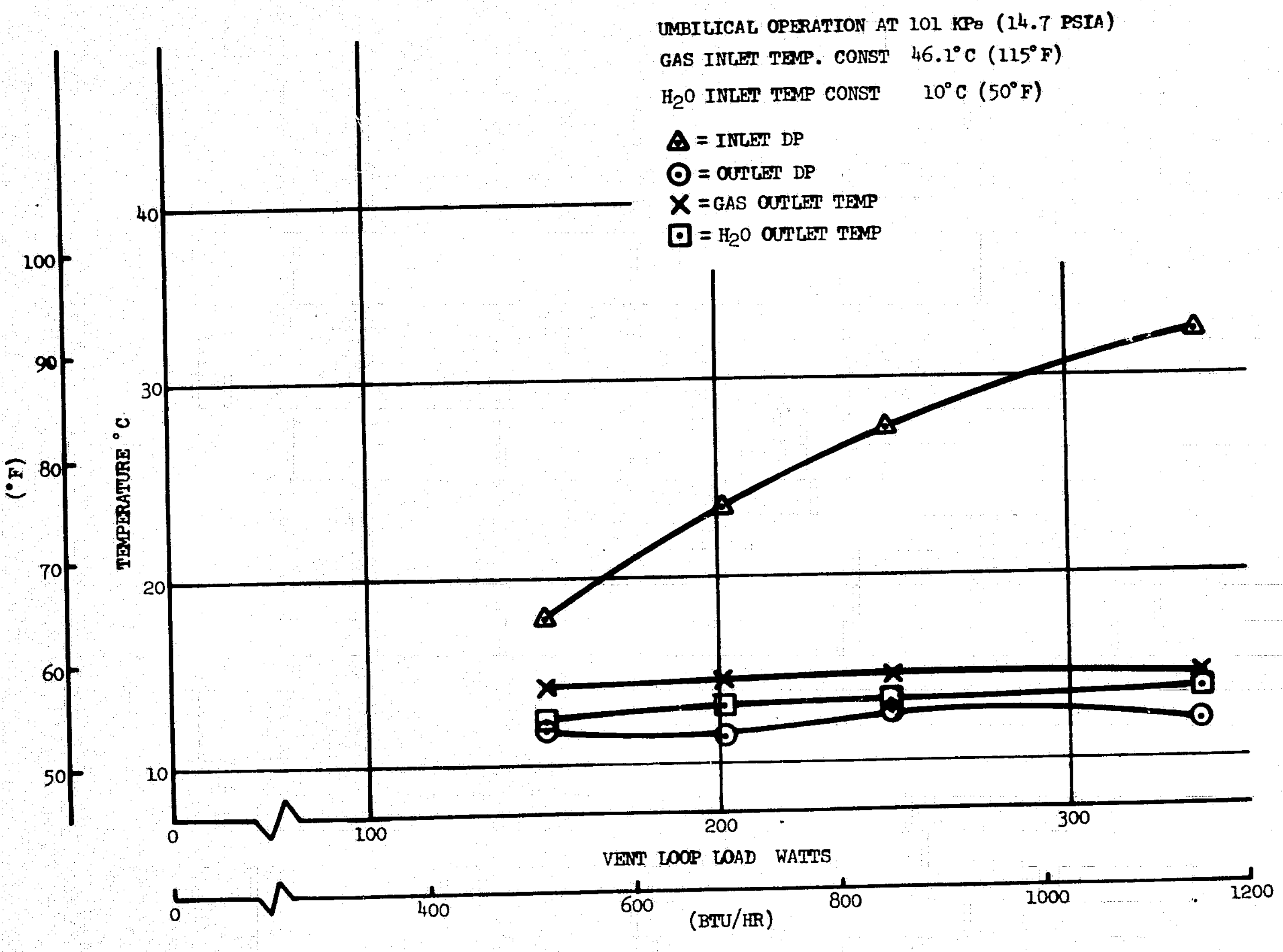
UMBILICAL OPERATION AT 101 KPa (14.7 PSIA)
GAS INLET TEMP. CONST 46.1°C (115°F)
H2O INLET TEMP CONST 10°C (50°F)
= INLET DP
= OUTLET DP
= GAS OUTLET TEMP
= H2O OUTLET TEMP
TEMPERATURE °C
(°F)
VENT LOOP LOAD WATTS
(BTU/HR)
40
30
20
10
100
90
80
70
60
50
0
100
200
300
400
600
800
1000
1200

FIGURE 4-5-8

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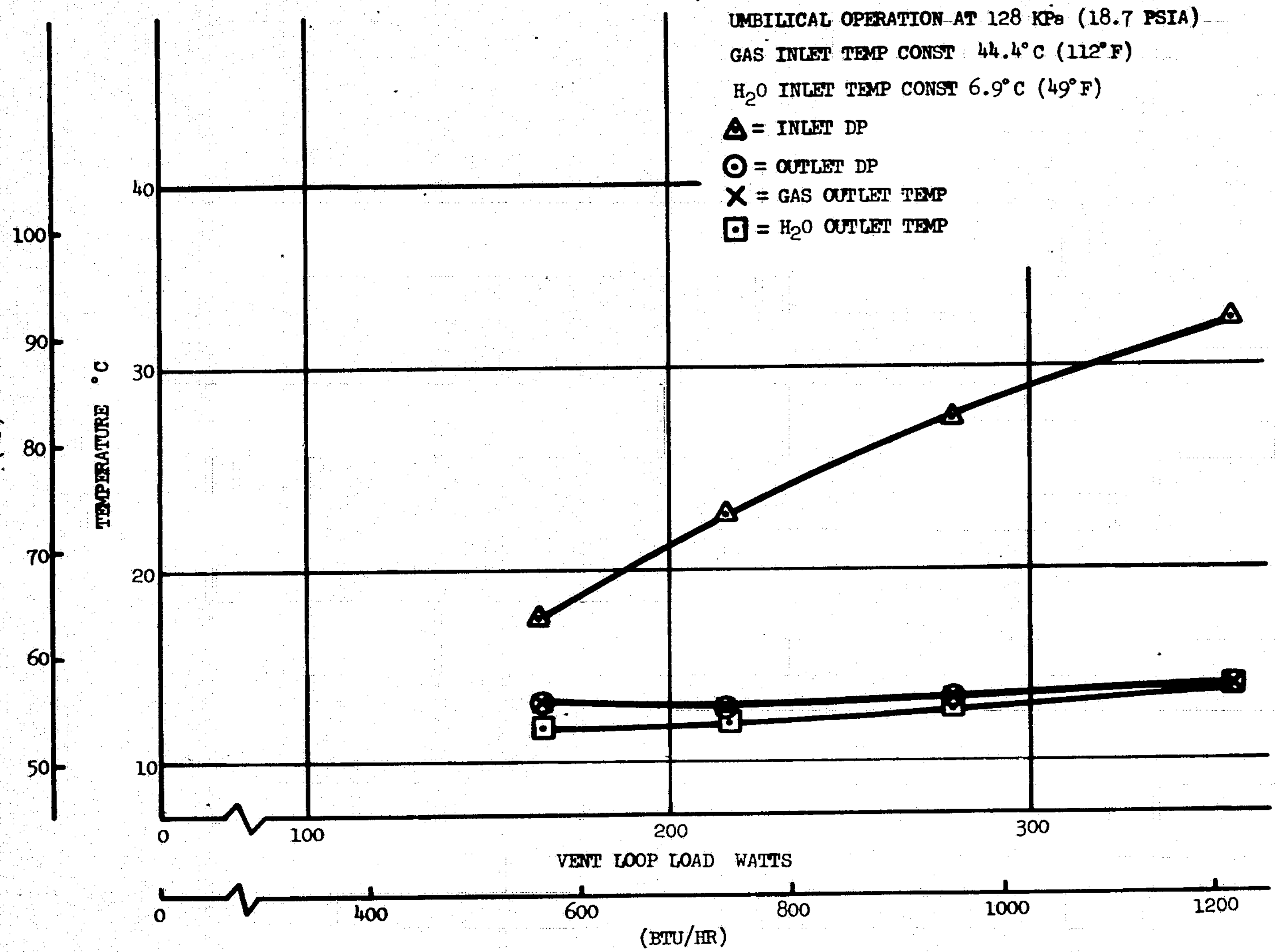

FIGURE 4-5-9

4.5 (Continued)

was verified by passing dry nitrogen through each circuit and observing the outlet dew point until three consecutive readings, taken at five minute intervals, were less than -17.8°C (0°F). Dry out verification required only 15 minutes per circuit.

5.0 CONCLUSIONS

The TCS program has defined an improved system for thermal control of a portable extravehicular mobility system for use in a zero "g" space application. The system is comprised of a replaceable plate sublimator for heat rejection, a bladder tank system for expendable water management, and a slurper/rotary water separator for ventilation condensate control. A gas separator, positive displacement pump, umbilical connector, and a manual flow control valve provide water transport control.

The hardware designs summarized in this report represent significant improvements over the comparable hardware used in the Apollo PLSS. These designs, which are supported by actual performance data, are lighter, require less power, are longer life, and more maintainable and less costly than hardware serving a similar function in the Apollo PLSS.

The TCS hardware, which is fabricated and tested in the program, meets all of the program performance requirements and represents new performance and system baseline for portable life support systems. The TCS provides a test bed vehicle which can be utilized to evaluate performance at off design conditions and provides a vehicle for evaluation of future system changes and component modifications.

6.0 RECOMMENDATIONS

The evolved TCS design requires a number of manual "user" operations or steps when using the system, especially in the area of servicing the Water Management Subsystem. Based on servicing experience gained with the TCS hardware, the risk of user error is believed to be significant. Design changes should be implemented in any flight design to reduce the number of operations required to service or use the system.

APPENDIX A

EVLSS THERMAL CONTROL SYSTEM

MINI SPECIFICATION

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1.0 INTRODUCTION

This "mini" specification defines the requirements for an Extravehicular Life Support System (EVLSS) Prototype Thermal Control System (TCS) which consists of a Heat Rejection Subsystem (HRS), a Water Management Subsystem (WMS), a Humidity Control Subsystem (HCS), and a Water Transport Subsystem (WTS).

2.0 APPLICABLE DOCUMENTS

MIL-STD-810B	Environmental Test Methods
MSCM-8080	Manned Spacecraft Criteria and Standards
MSC-SPEC-SD-W-0020	Potable Water Specification

3.0 REQUIREMENTS

3.1 Performance

3.1.1 Heat Rejection Subsystem

The Heat Rejection Subsystem (HRS) will use water as an expendable and will provide cooling for the oxygen loop and the liquid cooling loop of the EVLSS.

3.1.1.1 Oxygen Loop Parameters

3.1.1.1.1 Operating Pressure

The normal operating pressure within the oxygen loop will be 25.5-27.6 KPa (3.85 $\pm$ .15 psid) above ambient pressure. The unit must be capable of withstanding a pressure of 29.3 KPa (4.25 psid) and a collapsing pressure of up to 101 KPa (14.7 psia).

3.1.1.1.2 Maximum Heat Load

The HRS shall cool the oxygen loop to 10^{o}C (50^{o}F) maximum with the inlet conditions of 2.6 x 10^{-3} m^3/sec (5.5 ACFM) flow, 25.5 to 27.6 KPa (3.85 $\pm$ 0.15 psia) pressure, 43.33^{o}C (110^{o}F) temperature and dew point of 32.78^{o}C (91^{o}F).

3.1.1.1.3 Minimum Heat Load

The HRS shall cool the oxygen without freezing the condensed water with inlet conditions of 2.6 x 10^{-3} m^3/sec (5.5 ACFM) flow, 25.5 to 27.6 KPa (3.85 ± 0.15 psia) pressure, 22.22°C (72°F) temperature, and a dew point of 1.67°C (35°F).

3.1.1.1.4 Pressure Drop

The pressure drop in the oxygen loop shall not exceed 694 Pa (2.8 inches of water) under the conditions established in paragraph 3.1.1.1.2.

3.1.1.2 Liquid Loop Parameters

3.1.1.2.1 Operating Pressure

The normal operating pressure within the liquid loop will be 24.1 to 157.5 KPa (3.50 to 22.85 psia). The maximum normal pressure (non-operating) will be 246 KPa (35.7 psia).

3.1.1.2.2 Maximum Heat Load

The HRS shall cool the water loop to 7.22°C (45°F) maximum with inlet conditions of .03 Kg/sec (4.0 lb/min) flow and 12.22°C (54°F) temperature.

3.1.1.2.3 Minimum Heat Load

The HRS will cool but not freeze the water loop with an inlet heat load of 42 watts (144 Btu/hr) under the minimum flow conditions of the system. The maximum inlet temperature will be up to 26.67°C (80°F) depending upon selected concept.

3.1.1.2.4 Pressure Drop

The pressure drop in the water loop shall not exceed 5 KPa (.728 psi) with an inlet flow of .03 Kg/sec (4.0 lb/min) and an inlet temperature 7.22 to 12.78°C (45-55°F).

3.1.1.3 Start Up and Shutdown Requirements

3.1.1.3.1 Controls

As a design goal, the HRS shall be started up and shut down by a single control. A special start up position shall not be required.

3.1.1.3.2 Spillage

There shall be no water spillage when started up for each EVA. (Dry out within the prescribed shutdown period (five minutes) fulfills this intent.)

3.1.1.3.3 Start Up Time

The HRS shall be capable of rejecting the maximum heat load and meeting the performance requirements of paragraph 3.1.1.2.2 within 10 minutes after being turned on with a design goal of five minutes.

3.1.1.3.4 Shutdown Time

The HRS shall be non-venting within five minutes after shut off in a hard vacuum environment.

3.1.1.3.5 Start Up Conditions

3.1.1.3.5.1 Liquid Loop

The HRS shall be capable of start up with liquid loop temperatures from 10.0 to 37.78°C (50 to 100°F) and flow rate of .001 to .03 Kg/sec (.14 to 4 lb/min).

3.1.1.3.5.2 Oxygen Loop

The HRS shall be capable of start up with oxygen loop conditions of 10.0 to 37.78°C (50 to 100°F), dew point of 1.67 to 29.44°C (35 to 85°F), pressure of 25.5 to 27.6 KPa (3.85 $\pm$ .15 psia), and a flow rate of 2.6×10^{-3} m^3/sec (5.5 ACFM).

3.1.1.3.5.3 Expendable Water Circuit

The HRS shall be capable of start up expendable water supplied at the following conditions:

a. Temperature Range: 1.67 to 37.78°C (35 to 100°F)
b. Pressure Range: 25.5 to 246 KPa (3.70 to 35.7 psia)

Depending on the type of WMS and HRS, the expendable water may be fully saturated with N_2 and H_2 to a partial pressure of 3.33 KPa (25 mm Hg).

NOTE: The pressure range is based on vehicle imposed pressure on the WMS. In the event a higher or lower pressure is required to operate the HRS, the pressure range will be adjusted accordingly.

3.1.1.4 Maintenance

The HRS shall be capable of storage for 24 hours minimum at hard vacuum with no special preparation necessary to make it ready for an EVA cycle other than replenishing the expendable water supply. The HRS shall also be capable of start up, two hours operation, shutdown, and non-venting (non-operating) for 30 minutes, start up and 1 1/2 hours operation and final shutdown.

The HRS shall be capable of operating while being wetted during a mission cycle lasting up to 30 days before requiring any special servicing.

3.1.2 Water Management Subsystem

The WMS shall supply expendable water to the HRS as required and makeup water to the liquid cooling loop as required. The WMS may accept and store or use separated water from the HCS.

3.1.2.1 Fluid Capacity

3.1.2.1.1 Expendable Water

The reservoir shall be capable of holding a minimum of 3.45 Kg (7.6 pounds) of water when charged and of leaving a minimum amount of residual water when no longer capable of supplying water.

3.1.2.1.2 Separated Water

Water separated from the oxygen loop by the HCS may be stored or used as expendable water.

3.1.2.2 Fluid Pressure

3.1.2.2.1 Expendable water will be provided to the WMS at a pressure of 124 to 246 KPa (18 to 35.7 psia). As a design goal, the system shall be capable of working with water at 386 KPa (56 psid). After start up, the water pressure supplied to the HRS may be 25.5-27.6 KPa (3.85 ± .15 psid) depending on the HRS concept selected.

3.1.2.2.2 Separated Water

The separated water pressure will be TBD above ambient pressure. The expected pressure is 23-30 KPa (3.85 ± .5 psid).

3.1.2.3 Fluid Temperature

3.1.2.3.1 Expendable Water

The expendable water will be provided to the WMS at a temperature of 1.67 to 37.78°C (35 to 100°F).

3.1.2.3.2 Separated Water

The separated water temperature will be .56 to 32.22°C (33 to 90°F).

3.1.2.4 Fluid Processing

With the possible exception of removing gases, the WMS shall not process the water to be supplied to the HRS.

3.1.2.5 Contamination

The WMS shall not add contamination to the water to be supplied to the HRS.

3.1.3 Humidity Control Subsystem

The HDC will separate the condensed water from the oxygen loop portion of the HRS heat exchanger and will either store the water or deliver it to the WMS for storage or use as an expendable.

3.1.3.1 Storage Capacity

If the HCS stores the separated water, it shall be capable of holding a minimum of .77 Kg (1.7 lbs) of water, and it shall have drain provisions.

3.1.3.2 Separation Rate

The HCS shall separate a minimum of 5.3×10^{-5} Kg/sec (0.42 lb/hr) of condensate from the oxygen loop portion of the HRS.

3.1.3.3 Slugging

The HCS shall either prevent condensate slugging, or it shall be insensitive to slugging.

3.1.3.4 Orientation

The HCS shall separate water in any orientation with respect to gravity.

3.1.3.5 Oxygen Loop Parameters

The pressure drop of the oxygen loop portion of the HCS shall not exceed 89.6 Pa (0.36 inches of water) with oxygen loop flow of 2.6×10^{-3} m^3/sec (5.5 ACFM), temperature in the range of 40 to 90°F and pressure in the range of 25.5-27.6 KPa (3.85 $\pm$ 0.15 psia).

3.1.4 Relief Valve

The TCS shall incorporate a relief valve in the expendable water circuit. The valve shall be set at TBD.

3.1.5 Check Valve

The WMS shall contain a check valve to prevent water flow from the liquid cooling loop to the expendable water circuit.

3.1.6 Umbilical Operation

The TCS shall also be capable of being used with the HRS shutdown and connected to a spacecraft liquid cooling umbilical to provide cooling to both the vent loop and liquid cooling garment for a period of 4.5 hours. The TCS shall operate and remain safe, but may operate with selected degraded performance when operated with a spacecraft liquid umbilical.

3.1.7 Water Transport Subsystem

The Water Transport Subsystem (WTS) will circulate the cooling water, separate free gas from the water cooling circuit, provide a means for crewman to achieve thermal comfort, and shall provide a means for connecting the water cooling circuit to a spacecraft liquid cooling umbilical.

3.1.7.1 Water Circulation

The cooling water circulation shall be provided by a GFE SV713867 water pump.

3.1.7.2 Gas Separator

The gas separator shall separate the gas contained in the loop with maximum system water flow within five minutes. The device shall contain no moving parts and shall be valved to permit separated effluent gas to be vented continuously or at operator option. The gas will be introduced to the separator at a maximum rate of 35 cc/min.

3.1.7.3 Temperature Control Valve

The TCV shall allow cooling water to be bypassed around the inlet and outlet quick disconnect while allowing continuing full flow through the HRS. Valve end positions corresponding to "full warm" and "full cold" shall be provided with at least ten position indicating detents in between for partial bypass. The "full warm" position shall divert all but .68 to 2.05 kg/hr (1.5 to 4.5 lb/hr) around the inlet and outlet quick disconnects, while the "full cold" position shall supply 109 kg/hr (240 lb/hr) minimum to the outlet disconnect. Delta P across the valve (in any position) shall be 17.2 KPa (2.5 psid) maximum.

Simulation of the Temperature Control Valve function shall be provided by a GFE Skylab ALSA Water Diverter Valve.

3.1.7.4 Umbilical Connector

3.1.7.4.1 Operating Modes

There are two operating modes for the vehicle umbilical connector, coupled and uncoupled. Figure 1 and 2 show the two modes of operation respectively.

When the connector is coupled, all of the backpack water shall be directed to and from the umbilicals as shown in Figure 1. When the connector is uncoupled, all of the backpack water shall pass through the backpack half as shown in Figure 2. In the uncoupled mode, integral shutoff valves shall prevent overboard flow from either half of the connector. A redundant sealing cap shall be provided for the backpack half of the connector to prevent overboard leakage.

3.1.7.4.2 Coupled Performance

In the coupled mode at a water flow of 109 kg/hr (240 lb/hr), the delta P between the backpack water in port and the umbilical water in port shall not exceed 5.2 KPa (.75 psi), and the delta P between the umbilical water out port and the backpack water out port shall not exceed 5.2 KPa (.75 psi). In the coupled mode, the cross leakage between the backpack in port and backpack out port shall not exceed 2.3 kg/hr (5 lb/hr) with the backpack inlet port pressurized to 34.5 KPa (5 psig).

The external leakage shall not exceed .008 cc/min at a pressure of 34.5 KPa (5 psig).

3.1.7.4.3 Uncoupled Performance

In the uncoupled mode at a water flow of 1.09 kg/hr (240 lb/hr), the delta P between the backpack water inlet and the backpack water outlet shall not exceed .54 KPa (.25 psi).

The external leakage of the backpack half without the redundant seating cap shall not exceed .008 cc/min at a pressure of 34.5 KPa (5 psig).

The external leakage of the vehicle half shall not exceed .008 cc/min at a pressure of 34.5 KPa (5 psig).

3.1.7.4.4 Connecting Force

With the backpack and umbilical halves of the connector charged to 172.4 KPa (25 psig), the force to connect shall not exceed 89 newtons (20 lbs).

3.2 Useful Life

The useful life shall be a minimum of 100 mission cycles or 15 years, including up to 25,000 hours of mission related wet storage. The TCS will meet the requirements of this spec during its entire useful life. Replacement of limited life items is permitted during ground check out and maintenance operations during the useful life, but the limited life items shall be selected to meet the useful life requirements wherever feasible. Limited life item maintenance will not be permitted during orbital operations.

3.2.1 Mission Cycle

A mission cycle includes the following operations of an EVLSS with the TCS installed: preinstallation check out, installation in vehicle, launch, orbital operations including up to six EVA cycles, deorbit, landing, removal from vehicle, and post flight check out and maintenace.

3.2.2 EVA Cycle

An EVA includes the following operations of an EVLSS with the TCS installed: removal from vehicle stowage, donning, pre-EVA check out, start up, degrees from vehicle, return, shutdown, doffing, recharge of consumables, and stowage in vehicle. There may be as many as 600 EVA cycles during the useful life of the TCS.

3.2.3 Maintenance

There shall be no maintenance between EVA cycles in a mission other than recharge of expendable water and discharge of separated water. Ground servicing between missions shall be limited to 24 hours maximum, but shall include cleanliness verification/cleaning and performance check out as a minimum. Minimum maintenance and servicing shall be a design goal while still testing for all potential problems. Recharge of the TCS shall not require tools.

3.3 Natural Environments

The TCS will be packaged for all ground handling, shipping, and storage to protect it from the more severe earth environments such as rain, hail, sand and dust, etc. The TCS will be designed to withstand the following environmental requirements:

Temperature:	Transportation -42.78 to 71.11°C (-45 to +160°F) Storage -37.22 to 43.33°C (-35 to 110°F)
Pressure:	0 to 103.4 KPa (0.0 to 15.0 Psia)
Humidity:	0-100% R.H.
Sand and Dust:	Per Method 510 Procedure I of MIL-STD-810B
Salt Fog:	Per Method 509 Procedure I of MIL-STD-810B
Fungus:	Per Method 508 Procedure I of MIL-STD-810B
Acoustic Noise:	N/A
Gas:	Sea Level Ambient to 95 $\pm$ 5% by Weight Pure Oxygen

The environmental requirements are not imposed on the prototype TCS construction but must be met in the design of production TCS's. The differences between the prototype TCS and the production design shall be analyzed and reported. If production design is questionable in meeting any of the requirements, the prototype TCS shall be constructed such that tests can be performed to verify conformance to the requirement.

3.4 Induced Environments

3.4.1 Operating Fluids

3.4.1.1 Liquid Cooling Loop

The water in the liquid cooling loop will be per MSC Spec SD-W-0020, saturated with nitrogen and may include a bactericide. Depending on the TCS configuration, the liquid cooling loop could also contain some separated water.

3.4.1.2 Oxygen Loop

The oxygen loop operating fluid will be oxygen containing water vapor, carbon dioxide, and conductive and corrosive salts produced by the human body.

3.4.1.3 Separated Water

The separated water will come from the oxygen loop and may contain conductive and corrosive salts. It will be saturated with gas.

3.4.1.4 Expendable Water

Expendable water obtained from the vehicle will be per MSC Spec SD-W-0020, except total solids shall be 3.5 mm/liter maximum and may be saturated with N_2 and may contain H_2 at a partial pressure of 3.33 KPa (25 mm Hg) and may include a bactericide. Depending on TCS configuration, the separated water may also be used as an expendable.

3.4.2 Environments

The TCS shall withstand the following environments induced by the spacecraft:

Temperature:	1.67 to 37.78°C (35 to 100°F)
Pressure:	0 to 103.4 KPa (0.0 to 15.0 Psia)
Humidity:	0 to 100% R.H.
Gravity:	0.0 to 1.0 G's
Vibration:	Lift-off, transonic and q max - Acceleration spectrial density increasing at the rate of +9 dB/octave from 20 to 100 Hz; steady at 1 g^2/H_z to 250; decreasing at the rate of -6 dB/octave from 250 to 2,000 Hz. The vibration occurs for a duration of 70 seconds per flight.

3.4.2 (Continued)

Impact Shock: Normal leading 3.3 g saw tooth pulse with a rise time of 10 to 11 milliseconds and a decay time of 0 to 1 millisecond.

Crash 20 g saw tooth pulse with a rise time of 10 to 11 milliseconds and a decay time of 0 to 1 millisecond. Unit need not operate subsequently.

Acceleration: ± 3 g's maximum

The environmental requirements are not imposed on the prototype TCS construction but must be met in the design of production TCS's. The differences between the prototype TCS and the production design shall be analyzed and reported. If production design is questionable in meeting any of the requirements, the prototype TCS shall be constructed such that tests can be performed to verify conformance to the requirement.

3.5 Design

3.5.1 Structural Requirement

3.5.1.1 Proof Pressure

NOTE: The proof pressure shall be 1.5 times the maximum operating or relief valve pressure and shall be held for a minimum of five minutes.

3.5.1.1.1 Oxygen Loop

The oxygen loop shall be capable of operating within the requirements of this specification after being subjected to 41.3 KPa (6.0 psig) for five minutes.

3.5.1.1.2 Expendable Water Circuit

The expendable water circuit, with the water shutoff valve closed, shall be capable of operating within the requirements of this specification after being subjected to TBD KPa (TBD psig), upstream of the shutoff valve for five minutes.

The expendable water circuit loop, with the water shutoff valve open, shall be capable of operating within the requirements of this specification after being subjected to TBD KPa (TBD psig) for five minutes.

3.5.1.1.3 Water Separator Drain Loop

The water separator drain loop, with the water shutoff valve closed, shall be capable of operating within the requirements of this specification after being subjected to TBD KPa (TBD psig), downstream of the shutoff valve for five minutes.

3.5.1.1.4 Liquid Loop

The liquid loop shall be capable of operating within the requirements of this specification after being subjected to 620 KPa (90 psig) for five minutes.

3.5.1.2 Burst Pressure

3.5.1.2.1 Oxygen Loop

NOTE: The burst pressure shall be 2.0 times the maximum operating or relief valve pressure and shall be held for a minimum of five minutes. The oxygen loops shall not rupture but may permanently deform when subjected to 55.1 KPa (8.0 psig).

3.5.1.2.2 Expendable Water Circuit

The expendable water circuit, with the water shutoff valve closed, shall not rupture but may permanently deform when subjected to TBD KPa (TBD psig) upstream of the shutoff valve.

The expendable water circuit, with the water shutoff valve open, shall not rupture but may permanently deform when subjected to TBD KPa (TBD psig).

3.5.1.2.3 Water Separator Drain Loop

The water separator drain loop, with the water shutoff valve closed, shall not rupture but may permanently deform when subjected to TBD KPa (TBD psig) downstream of the shutoff valve.

3.5.1.2.4 Liquid Loop

The liquid loop shall not rupture but may permanently deform when subjected to TBD KPa (TBD psig).

3.5.2 Weight and Volume

The TCS size and weight must be minimized in order to be part of an extravehicular life support system worn by a crewman. The size and weight requirements are not imposed on the prototype TCS but must be met in designing production or flight TCS's. The differences between the prototype TCS and the production design shall be analyzed and reported. If the size and weight are important factors in meeting the requirements of this SOW, then the prototype TCS shall be constructed such that tests can be performed to verify conformance to the requirements with a system of practical size.

3.5.3 General Design Requirements

3.5.3.1 General

The TCS shall meet the applicable requirements of MSCM 8080.

APPENDIX B

THERMAL CONTROL SYSTEM

INSTRUMENTATION STUDY REPORT

1.0 INTRODUCTION

This report describes the results of the Thermal Control System Instrumentation study.

2.0 PURPOSE

The purpose of the study was to identify the TCS instrumentation necessary to furnish caution and warning information for crew safety and performance monitoring.

3.0 CONCLUSIONS AND RECOMMENDATIONS

It was concluded that O_2 tank pressure, suit pressure, O_2 vent flow, CO_2 partial pressure, transport water temperature, battery current and battery voltage instrumentation are required to provide caution and warning information in an EVLSS.

All of this instrumentation, with the exception of the transport water temperature sensor, would be located outside of the thermal control subsystem. It is, therefore, recommended that a transport water temperature sensor be incorporated in the Thermal Control System.

4.0 DISCUSSION

The basic approach utilized for the EVLSS instrumentation study was to conduct a preliminary FMEA which identified gross failures and established a preliminary set of backpack instrumentation. A more detailed FMEA which considered component failure modes was then conducted to verify the adequacy of the instrumentation. In addition, a probable operating sequence summary was generated to establish operational modes for use in the final FMEA. The preliminary FMEA, the final FMEA, and the operating sequence summary are included as Tables 1, 2, and 3 respectively. The assumed EVLSS schematic utilized in this study is shown in Figure 1.

The following summarizes the warning instrumentation requirements identified by the preliminary FMEA study and discusses the failure mode detection capability of each sensor.

	Measurement	Warning	Gage Readout
1)	O_2 Tank Pressure	Low Pressure	Yes
2)	O_2 Total Pressure (PGA)	Low Pressure	Yes
3)	O_2 Ventilation Flow Rate	Low Rate	No
4)	CO_2 Partial Pressure, at Helmet	High Pressure	Yes
5)	Transport Water Temperature	No	Yes
6)	Battery Current	No	Yes
7)	Battery Voltage	Low Voltage	Yes

4.0 (Continued)

PGA Pressure

High pressure is not a hazard since the suit relief valve is a protective device to prevent pressures which immobilize or burst the suit. A low pressure could be due to a massive O_2 leak, or failed-open relief or purge valve, a fail-closed regulator, or failed pressure transducer. If it occurs gradually, it can be compared with the wrist gage, a suit inspection can be made, and an abort decision might be postponed. If it occurs suddenly, it calls for immediate abort on purge flow. Warning is required. Low pressure combined with other symptoms of abnormality must be handled similarly.

CO_2 Partial Pressure

High CO_2 level alone may be due to a sensor failure or failure of absorption. It calls for abort since there may be no other danger signal from a failure of CO_2 absorption. High CO_2 partial pressure due to loss of gas or lack of vent flow would be combined with vent flow, pressure, voltage or current anomalies, and must also be acted upon immediately.

If possible, it is desirable for a functioning CO_2 sensor to display a different readout than a failed sensor. Since CO_2 partial pressure is normally zero, a failure of the sensor might otherwise be undetected.

O_2 Tank Pressure

O_2 tank pressure and its change are a key to performance to the TCS and the astronaut. Normally decreasing pressure demonstrates the integrity of the pressurized system, given a knowledge of the EVA work level. Observed from time to time as the EVA proceeds, pressure permits verification that the mission can be carried to its planned duration. Rapidly decreasing pressure, beyond that required for the work or stress level of the astronaut, implies an oxygen leak not yet massive enough to activate the suit pressure alarm. This serves to alert the crew to possible incipient failure and allows the mission duration to be matched to the oxygen quantity.

An abnormally high oxygen tank pressure probably represents a failed transducer. The suit pressure transducer then would be used to indicate gas supply depletion.

Low oxygen could be due to an oxygen leak or a failed transducer, and in either case, the action must be to abort on purge flow. Warning is desirable even though safety is provided by the PGA low pressure warning. Low pressure combined with other symptoms must be handled similarly.

4.0 (Continued)

Water Temperature

Water temperature is not significantly affected by variations in load since the sublimator is self-regulating, thus, high water temperature in the transport loop is evidence of a failed porous plate or exhaustion of transport water and feed water. Water loss could be:

a) By leak in the feed water system
b) By porous plate breakthrough
c) By leak of the transport water

Therefore, if water temperature rises above a normal variation, preparation should be made to abort - the vent gas and LCG will soon begin to feel hot, and a small oxygen loss would occur through the gas separator if transport water is leaking.

Abnormally low temperature of transport water indicates lack of flow through the LCG for any reason. An accompanying low battery current may indicate an open electrical circuit or pump inadvertently shut off.

If water flow is lost, the LCG will begin to feel hot, and abort with purge flow for maximum cooling effect may be desired.

Ventilation Flow Rate

Low ventilation flow implies a failed fan or electronics, an obstruction in the loop, or a failed transducer. Since no more than one minute of stagnation is safe, abort on purge flow is necessary in the event of low vent flow. The loss of flow would be accompanied by rapidly rising partial pressure if the CO_2 is measured at the point of inhalation.

Battery Current

Battery current level can be used to establish that all electrical items are operating normally. A current reading outside of the normal operating band would be warning of an impending anamoly or that one or more of the devices had not been turned on or had been inadvertently shut off.

Battery Voltage

Battery voltage should be measured to ensure the availability of all instruments and warnings. Either voltage should be monitored periodically or there should be a separately powered warning signal for low voltage. Low voltage is cause for abort.

4.0 (Continued)

The transport water temperature measurement provides advance warning of failures which will result in the astronaut feeling hot. Although a failure will become evident by "feeling" alone, the trend available from the temperature readout permits early attention and unhurried response. High CO_2 level warning could substitute for low ventilation flow, and low PGA pressure could substitute for low oxygen tank pressure. This is not recommended, as the redundant warnings against serious failures increase the safety.

The symptoms and effects revealed by the FMEA established that decisions should be based on single symptoms or on multiple symptoms if one or more of these call for use of the emergency system and abort. In a few cases, simple diagnostic actions may be taken which permit mission continuance as summarized below.

Summary of Crew Actions in Event of Abnormalities

Abnormalities (Singly, Or With Others)	Action
PCG Pressure - High	Monitor
Low	Abort
CO_2 Partial Pressure - High	Abort
O_2 Tank Pressure - High	Probable sensor failure. Continue EVA as suit pressure will indicate when gas supply is depleted.
Low	Abort
Ventilation Flow - Low	Abort
Water Temperature - High	Prepare to abort.
Low	Act to prevent freezing of sublimator.
Battery Current - High	Pre egress, check that all items turned on. EVA, monitor or abort.
Low	Diagnose
Battery Voltage - High	Monitor
Low	Abort
Water or Noxious Gas in Face Area	Abort

4.0 (Continued)

Initial warnings should be audible warnings since these are immediately perceived by the astronaut no matter where his attention may be directed. Following the audible warning, audible and/or visual information and/or corrective instructions should be relayed to the crewman.

Transport water temperature and battery current do not require warnings, but provide evidence of normal performance or advance evidence of a failure. These should also be available as a readout of the measured value. This study was based on the premise of independence of the astronaut on EVA. Therefore, the readouts should be available directly to him. The presence or absence of telemetry was not dealt with in this study. However, if it is decided that the EVA should be monitored from the spacecraft, it would be recommended that all the measurements have a qunatitative readout at the receiving station.

To obtain maximum value from the proposed instrumentation, the sensors should be located as listed below.

Sensor	Location
Suit Pressure	At the PGA
O_2 Tank Pressure	At the O_2 tank outlet
CO_2 Partial Pressure	Sampling just upstream of point of inhalation in the helmet
Ventilation Flow	In vent circuit
Transport Water Temperature	At sublimator outlet
Battery Current and Voltage	Between battery and distribution box

Of these instruments, only the transport water temperature sensor is located in the Thermal Control portion of an EVLSS and, thus, is the only sensor which is included in the TCS.

TABLE 1
PRELIMINARY SYSTEM FMEA

Failure Mode	Possible Cause	How Detected	How Counteracted
LiOH Dusting	Crushed LiOH and/or failure in nomex filter	Oral-Nasel Irritation	Abort on purge flow.
Smoke, smell, vomit, water globules in gas stream, etc.		Crew senses	Abort on purge flow.
High Suit Pressure	From supply Regulator fails open	Suit mobility O_2 pressure sensor	Shut off O_2. Abort on emer. Regulated flow.
Water in gas stream	Slurper clogged	Visual	Abort on purge flow if amount of moisture is intolerable.
	Separator stopped	Visual	Shut off separator. Abort on purge flow.
Fan/Separator motor fails	Short circuit	No vent flow Visor fogging	Shut off fan separator. Abort on purge flow.
Loss of both gas and water cooling	Loss of feedwater Loss of power Hx malfunction	Gas feels hot. Suit feels hot. Water temp. increases. No vent flow.	Abort on purge flow.
Feed water bladder rupture through to pressurization line and gas circuit	Overpressure	Visual	Abort on purge flow.

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TABLE 1
(Continued)

Failure Mode	Possible Cause	How Detected	How Counteracted
Water too cold	TCV valve seizes	Crew observation	Same as above or shut off pump intermittently.
Fill and drain couplings. Won't couple or uncouple.	Distorted or contaminated	Crew observation	Cannot use EVLSS.
Loss of power		Battery current and voltage	Abort on purge flow.
Loss of O_2	Leak	O_2 tank pressure rate of decrease	Abort on regulated flow.
Excess use of power	Electrical short	Battery current and voltage	Monitor and shorten mission.
Loss of transport water followed by loss of feed water	Leak or double failure of subli-mator or break-through and fail-ure of check valve	Visual Suit feels hot.	Abort on purge flow.
Lack of transport water flow	Pump failed	Suit hot. Water temperature low.	Abort on regulated flow. Shut off pump.
	Loop clogged	Suit hot. Water temperature low.	Abort on regulated flow. Shut off pump.
	Loss of pressure (cavitation) check valve failed closed	Suit hot. Water temperature low.	Abort on regulated flow

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TABLE 1
(Continued)

Failure Mode	Possible Cause	How Detected	How Counteracted
Water too hot	Loss of feed water	Crew observation	Abort on purge flow.
	Sublimator breakthrough		
	Partially clogged porous plate		
	Feed water valve won't open	Crew observation or no drop in water temp.	Do not initiate EVA.
	TCV valve seizes	Cannot adjust temperature to comfort level.	Abort on purge flow if too distressing.

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TABLE 2

20 PAGES

TCS DETAILED FMEA

Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	Effects: PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Suit Outlet O_2 Connector													
	Won't connect, due to distortion or contamination.											Crew Observation	NA	None, unless crew can straighten or free the connector. TCS of no further use until repaired.
	Won't disconnect											Crew Observation	NA	Must leave TCS coupled to suit.
	Leaks When Uncoupled											No Effect	No Effect	
	Leaks When Coupled	*X_1		X_2		X_3							Depends on note	Abort on regulated flow
	Suit Inlet O_2 Connector												Same as Above	Same analysis as above
	LCG Connector													
	Won't connect due to distortion or contamination											Crew Observation Cannot use TCS	NA	None, unless crew can straighten or free the connector. TCS of no further use until repaired.
	Won't disconnect											Crew Observation	NA	Must leave TCS coupled to suit.
	Leaks when uncoupled											Free water in Cabin	NA	Cap, or tape the connector.
	Leaks when coupled						X					Gas and suit feel hot-unless it seals with an ice dam.	Five minutes after feeling hot.	Abort on purge flow. Note that the tank bladders prevent loss of O_2 at tanks after exhaustion of water. However, O_2 would back flow through gas separator. Gas separator valve should be closed.
	Vehicle Umbilical Connector													
	Won't connect due to distortion or contamination.											Crew Observation	NA	Operate without vehicle umbilical. (Less comfortable)
	Won't disconnect											Crew Observation	NA	Further EVA depends on redundancy of vehicle umbilical and PLSS units.
	Leaks when uncoupled						X					Gas and LCG feel hot, unless it seals with an ice dam.	Five minutes (See remarks)	Abort on purge flow.
	Leaks when coupled, including adjacent lines a. External											Crew observation when uncoupling	NA	Recharge and start up without vehicle umbilical
	b. Internal						X					Decreased flow rate in TCS	NA	Start up without vehicle umbilical.
	Battery Connector													
	Won't connect or disconnect											Crew observation	NA	TCS of no further use. In the case of "won't disconnect," the TCS could be used if battery can be charged "in place"

*Subscripts indicate order of appearance of symptoms

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TCS DETAILED FMEA (Cont'd)

Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	Effects: PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Battery Connector (Cont'd)													
	Short Circuit								X_1		X_2		One Minute after Fan Stops	Scrub or abort mission whenever low voltage is detected.
	Open Circuit										X		One Minute after Fan Stops	Scrub or abort mission whenever low voltage is detected. An open circuit which disables an instrument will be considered under the instrument entry in this analysis.
	Dump Valve, O_2													
	Won't open, due to contamination, seat swelling or the like											Crew observation	NA	May be able to relieve gas by depressing the O_2 coupling poppet at a suit-to-TCS coupling. If not, TCS cannot be charged fully. Mission would be shortened.
	Won't close											Crew observation	NA	May provide a cap for the valve outflow, useful for cleanliness purposes as well.
	Leaks (small leak), seat, stem, or housing.	X_1		X_2		X_3						Mission would be shortened.	When pressure drops to 20.7 KPa (3.0 psi)	Note: If there is a cap, the valve failure would have no effect, unless it is a stem or housing leak.
	Temperature Control Valve TCV													
	Won't shift due to contamination.											Crew observation. Loss of ability to adjust cooling.	NA	None. Abort if discomfort is excessive.
	Internal leak due to seal deterioration.											Crew observation that range of adjustment of temperature is lost on one end of the band.	NA	None
	External leak, stem, or housing.						X					Gas and LCG feel hot, unless leak seals with an ice dam.	Five Minutes	Abort on purge flow
	Feedwater Valve													
	Won't open, due to contamination, seat swelling, or the like.											Crew observation	Five Minutes	Scrub mission
	Won't close											Crew observation. Inability to charge the TCS with water without loss of water through sublimator.		Scrub mission. TCS of no further use until repaired. However, see remarks below, for valve between tanks failing to close.

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TCS DETAILED FMEA (Cont'd)

Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	Effects: PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Feedwater Valve (Cont'd)													
	Leaks internally due to seal deterioration.											Crew observation of water escaping through the porous plate.		Continue the EVA mission, but shorten it to account for loss of water.
	Leaks externally (upstream leak).											Crew observation pre-egress		Same as above
							X					During EVA this may go unnoticed until water is prematurely exhausted and gas gas and LCG feel hot.	5 Minutes	Abort on purge flow.
	Downstream leak						X					Gas and LCG feel hot.	5 Minutes	Abort on purge flow.
	Valve Between Water Tanks													
	Won't close (for charging phase).											Crew observation. If charged without closing, sublimator may be over-stressed on opening feed-water valve.	NA	Scrub mission, unless tests have previously demonstrated the tolerance of the sublimator to overstresses of the intensity involved.
	Won't open											Crew observation. No cooling can be obtained from the TCS.	NA	Scrub mission. TCS of no further use until repaired.
	Leaks internally due to seal deterioration.											If the leak is significant, the porous plate would break through upon opening the feedwater valve, and be observed. The porous plate may be overstressed by the pressure of the water.	NA	Scrub mission, unless tests have previously demonstrated the tolerance of the sublimator to overstress of the intensity involved.
	Leaks externally (upstream leak).											Crew observation when charging.	NA	Scrub or shorten mission.
	(Downstream leak)						X					Crew observation when valve is opened at conclusion of charging. If not noticed then, it would be detected when gas and LCG feel hot.	NA or 5 Minutes	If detected, continue the mission, but shorten it to account for loss of water. If not detected, abort on purge flow when temperatures rise.

Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	Effects: PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Gas Separator Valve													
	Won't close											Crew observation when attempting to close prior to charging the TCS with water. Effect would be to flood the air circuit with water during filling, which would be blown into the helmet area before the fan/sep. could pump it out.	NA	Scrub mission. TCS of no further use until repaired.
	Won't open											Crew observation when attempting to open during a startup. Effect would be possible pump cavitation and loss of liquid flow.	NA	Scrub mission. TCS of no further use until repaired.
	Leaks internally											The effect would be to flood the air circuit with water which would be blown into the helmet area before the fan/separator could pump it out. However, this should occur prior to donning the helmet, and thus would not pose a hazard of water ingestion.	NA	If the flow of water globules subsides, as it should when the feedwater pressure rapidly subsides to O_2 loop pressure, the mission may be undertaken.
	Leaks externally (upstream leak)	X_2		X_3		X_4		X_1				Crew observation of water leak. If not noticed, it would be detected later as a pressure decay, after the valve is opened and the helmet is donned.	NA or 5 minutes	Scrub mission. TCS of no further use until repaired. If not detected, abort on regulated flow when temperatures rise.
	(downstream leak before opening valve)											Undetectable loss of O_2	NA	
	(leak after opening)	X_2		X_3		X_4		X_1				Mission would be shortened.	When pressure drops to 20.7 KPa(3.0 psi).	Abort on regulated flow.
	Fill Connector and Cap													
	Won't connect, due to distortion or contamination											Crew observation	NA	TCS of no further use until repaired, since the fill and drain connectors are not interchangeable. If the distortion has occurred on the vehicle, further EVA depends on redundancy of vehicle fill connector.

Item	Name and Failure Mode	or Lo Use Press.	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptons and/or Effects	Time to Emerg. Level	Corrective Actions
	Fill Connector and Cap (Cont'd)													
	Won't disconnect, due to jamming											Crew observation	NA	Further EVA depends on redundancy of vehicle fill connector and PLSS.
	Leaks when connected											Crew observation		Disconnect and reconnect to attempt to flush connector. If leak persists, continue charging unless leak cannot be mopped up.
	Leaks when disconnected, TCS half.						X					Crew observation. If not noticed it would be detected when gas and LCG feel hot, unless leak seals with an ice dam.	Five minutes after feeling hot.	The cap provides a redundant seal. Thus, there would be no problem unless a double failure occurred.
	Drain Connector and Cap													
	Won't connect, due to distortion or contamination											Crew observation	NA	TCS of no further use until repaired, since the fill and drain connectors are not interchangeable. If the distortion has occurred on the vehicle half, further EVA depends on redundancy of vehicle drain connector.
	Won't disconnect, due to jamming											Crew observation	NA	Further EVA depends on redundancy of vehicle drain connector and PLSS.
	Leaks when connected											Crew observation. Loss of a certain amount of water into the airlock.	NA	If the water can successfully be mopped up, the EVA mission can be continued.
	Leaks when disconnected, TCS half						X					Crew observation. If not noticed, then it would be detected when gas and LCG feel hot, unless leak seals with an ice dam.	Five minutes	The cap provides a redundant seal. Thus there would be no problem unless a double failure occurred.
	Instrument Electrical Connector													
	Cannot connect to RCU											Crew observation upon donning backpack.	NA	TCS and/or RCU cannot be used until repair is accomplished.
	Cannot disconnect from RCU											Crew observation upon doffing backpack.	NA	Must leave backpack coupled to RCU. Note: The design may include sufficient integration to eliminate this failure mode.

Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Instrument Electrical Connector (Cont'd)													
	Short circuit, pin to pin or open circuit								X_1		X_2	One or more instruments will saturate to high or low readout, depending on the circuits. Battery will be discharged prematurely.	See corrective action	If a warning is caused, the indicated abort action must be taken if the failure occurs while on EVA, or scrub action if pre-egress on EVA. TCS and/or RCU of no further use until repaired. If a warning is not caused, but measurements are abnormal, the action would be based on the apparent abnormality unless a saturated instrument is outside of all possible failure conditions. If the instrument failure is isolatable based on the type of readout, a decision will be made on further action.
	Fan/Separator Switch													
	Won't turn on				X					X		By observation of switch, or crew detects lack of feeling or ventilation flow and lack of hum of the fan, also.	NA since it is detected prior to donning helmet.	Scrub the EVA. TCS of no further use until repair is accomplished.
	Won't turn off								X			By observation of switch, or crew continues to feel flow and hear the fan after switching.	NA	Shut off by disconnecting the battery connector. Can use the TCS (in degraded condition) by use of battery connector as substitute or fan switch.
	Turns off inadvertently				X	X				X		By observation of visor fogging. Feel lack of ventilation.	One minute after fan stops	Turn switch on if possible. If not, abort on purge flow.
	Switch at battery potential											Shock felt, if switch touched with bare hands before donning gloves.	Immediate	TCS not to be used until repair accomplished.
	Pump Switch													
	Won't turn on.							X		X		By observation of switch, or crew doesn't feel the expected cooling.	NA since it is detected before being committed to EVA.	Scrub the EVA. TCS of no further use until repair is accomplished.

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Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Pump Switch (Cont'd)													
	Won't turn off								X		X	By observation of switch, or crew continues to hear pump.	NA	Shut off by disconnecting the battery connector. Can use the TCS (in degraded condition) by use of battery connector as substitute for pump switch.
	Turns off inadvertently							X		X		Suit feels hot	20-30 minutes	Turn switch on if possible. If not, abort if body temperature rises.
	Switch at battery potential											Shock felt, if switch touched with bare hands before donning gloves.	Immediate	TCS not to be used until repair accomplished.
	Fan Separator													
	Mounts break													Mounts are redundant. Three out of four are sufficient to hold the unit in place.
	Seals fails, separator to volute or volute to motor.	X_1		X_2		X_3							When pressure drops to 20.7 KPa(3.0psi).	Abort on regulated flow. Flight design may have redundant sealing.
	Seals fails, separator water outlet						X					Gas and LCG feel hot when water is exhausted prematurely.	Five minutes after feeling hot.	The .4Kg(.9#)of separator water adds to the 3.2Kg (7.1#)minimum to be charged into the Shuttle backpack, to provide a 4 hr. mission. Note, however, that the development TCS holds 3.8Kg(8.3#) of water. It is considered unlikely that the leak cause freezing of the separator outlet.
	Separator rotor loosens due to nut loosening.											The rotor stops turning, the motor may be jammed. The slurper water is fed back into the gas stream, and carries over into the helmet area occurs. Fan may stop causing vent flow and CO_2 sensors to react.	Moisture can be felt as it gradually becomes worse.	Abort on purge flow.
	Separator rotor insert loosens											Rotor could be jammed against stator. Slurper water would then be fed back into the air stream and carry over into the helmet area would occur. Fan may stop causing CO_2 and vent flow sensors to react.	Same as above	Abort on purge flow. Note that there normally is no water at the outer slinger disc.

Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	PGA Press.		Vent Flow	CO_2 Press.	H_2O Temp.		Batt. Current		Batt. Volts	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
			Hi	Lo	Lo	Hi	Hi	Lo	Hi	Lo	Lo			
	Fan Separator (Cont'd)													
	Pitot clogs											Water carryover. Slurper water is fed back into the air stream and carry over into the helmet area occurs.	Moisture can be felt as it gradually becomes worse.	Abort on purge flow. Note: Redundant pitots will be considered for the flight design.
	Separator central stator loosens				X	X						It may rub against the rotor and slow the speed of the unit, causing lower gas flow and water carryover.	Depends on rate of increase of CO_2 partial pressure.	Abort on purge flow.
	Separator rotor fracture.				X	X						Pieces could jam the unit, causing loss of gas flow.	One minute after loss of gas flow.	Abort on purge flow upon warning. Note: Containment analysis or test must be carried out to prove that the case will not be punctured. Critical speed analysis is needed to ensure that the rotating elements cannot come into vibratory resonance.
	Fan impeller fracture				X	X						Loss of gas flow.	Same as above.	Same as above. Note: Motor speed is 1790 rad/sec (17,700 RPM). Calculated burst speed is greater than 10,470 rad/sec(100,000 RPM.
	Fan impeller loosens, due to nut loosening				X	X						Decrease or loss of gas flow.	Same as above.	Same as above.
	Fan impeller rubs													Impeller is sufficiently rigid not to deflect. Axial clearance is $2.58x10^{-6}$m to $5.x10^{-6}$m(0.004" to 0.008"). Radial clearance is $1.9x10^{-6}$m (0.003").
	Motor to volute bolts loosen													The connection is pinned to preserve alignment. The bolts are multiply redundant.
	Motor cover plate loosens, if screws loosen.				X	X						Decrease or loss of flow due to moving parts being jammed against stationary.	Same as above.	Abort on purge flow.
	Motor bearing wear, due to faulty lubrication or exhaustion of grease.				X	X			X			Speed of the unit slowed, causing lower axis flow and water carryover.	Depends on rate of increase of CO_2 partial pressure.	Abort on purge flow.
	Motor bearing seizes.				X	X			X			Loss of gas flow.	One minute after loss of gas flow.	Abort on purge flow.
	Lubricant vapor in air stream.													Rate of vaporization is minute.
	Motor bearing preload spring breaks or spring slide jams.											No effect. Unit is shimmed so that rubbing cannot occur, while still allowing for thermal expansion.		
	Motor shaft breaks				X	X						Loss of gas flow.	One minute after loss of gas flow.	Abort on purge flow. Probability very small due to steady state strength margin. Analysis or test must be done for resonances.

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Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Fan Separator (Cont'd)													
	Permanent magnets come loose from rotor				X	X						Motor probably will become locked. Loss of air flow. The cut-off will turn off power.	One minute after loss of gas flow.	Abort on purge flow.
	Short or open in motor windings.				X	X			X				One minute after loss of gas flow.	Abort on purge flow.
	Short or open in hall-effects sensors				X	X			X			Motor will operate on one of the two phases. Speed will decrease and current will increase. Decrease or loss of air flow.	One minute after loss of gas flow.	Abort on purge flow.
	Sensor plates loosen and move out-of-adjustment.				X	X			X			If the plates loosen, they probably will move enough so that speed decreases. There would then be loss of gas flow.	One minute after loss of gas flow.	Abort on purge flow.
	Motor nut loosens and backs off.											No effect. The bearing will maintain the shaft in position. The direction of motion will tend to retighten the nut if it backs off enough to touch the housing.		
	Armature (stator) members loosen.				X	X			X			Motor probably will become locked. Loss of gas flow.	One minute after loss of gas flow.	Abort on purge flow.
	Rotor jams against armature, due to contamination.				X	X			X			Motor will be locked. Loss of gas flow. The cut-off will turn off power.	One minute after loss of gas flow.	Abort on purge flow.
	Motor cooling cavity leak (external).						X					Loss of water. Gas and LCG become hot after feedwater is exhausted through the leak.	Five minutes after feeling hot.	Abort on purge flow.
	LiOH Canister													
	Cover won't open, or won't latch.											Crew observation when charging.	NA	TCS of no further use until repair accomplished.
	Canister jammed in canister due to swelling or contamination.											Same as above.	NA	Same as above.

Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Dusts, due to faulty filter and excessive powdering of LiOH.											Oral nasal irritation.	No emerg. limit	Abort on purge flow.
	Prematurely exhausted due to previous use or exposure of canister.					X							One minute after exhaustion of canister; but CO_2 PP will rise before complete exhaustion.	Abort on purge flow.
	Internal leak											No effect unless severe. If severe CO_2 level will climb.	NA	Abort on purge flow.
	Bed channels					X						CO_2 level will climb.	Gradual rise of CO_2 PP.	Abort on purge flow
	Wet canister due to respiration or perspiration.											None. Canister will absorb moisture early in mission and evaporate it later as heat is developed.	NA	None required
	Contaminated by vomit.				X	X							One minute after flow is clogged.	Abort on purge flow.
	External leak of canister or adjacent lines.	X_1		X_2		X_3						No other symptoms.	When pressure drops to 20.7 KPa (3.0 psi).	Abort on regulated flow.
	Mounts break due to vibration.	X		X										Note: Design and development testing should be such that this failure mode has insignificant probability. If it did occur, oxygen integrity might be lost. Low oxygen warnings would lead to abort.
	Sublimator and Slurper													
	Porous plate clogs with contaminant or corrodent.						X					Gas and LCG feel hot.	Five minutes after feeling hot.	Abort on purge flow. Note: The temperatures at the sublimator outlet would increase gradually over many missions before the plate became fully clogged.
	Porous plate fracture due to overstress cycles.						X					Gas and LCG feel hot after feedwater is exhausted through the leak.	Five minutes.	Abort on purge flow.
	Porous plate breakthrough, due to overpressure, thermal overload or deteriorated plate.						X					Gas and LCG feel hot.	Five minutes.	May be possible to shut off and restart the sublimator. Otherwise, abort on purge flow.

Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Sublimator and Slurper (Cont'd)													
	Feedwater leak, external (sublimator or adjacent lines)						X					Gas and LCG feel hot after feedwater is exhausted through the leak.	Five minutes	Abort on purge flow.
	Gas leak, external (sublimator or adjacent duct including slurper water outlet)	X_1		X_2		X_3						Effect on ventilation flow depends on size of leak and location of vent flow sensor.	When pressure drops to 20.7KPa(3.0 psi).	Abort on regulated flow.
	Leak, transport water to feedwater											No effect		
	Leak, transport water to gas circuit											If the leak is small, the slurper may collect the water. If not, there will be water carryover to the helmet area, detected by seeing droplets on visor.	Gradual	If distressing, abort on purge flow. The leak rate could be reduced or stopped by shutting off the pump, sacrificing the LCG. Design precludes this failure mode.
	Slurper holes plug											Water carryover to the helmet area detected by seeing droplets on visor.	Gradual	Abort on purge flow.
	Slurper bypasses excessive air											Decreased ventilation flow to helmet, but not critical.	Not critical	Note: At normal metabolic loads, flow is sufficient to helmet even if slurper were dry $1.8 \times 10^{-3} m^3/sec$ (3.0 cfm) .
	Slurper loss of hydrophilic coating											Water carryover to helmet area detected by seeing droplets on visor.	Gradual	Abort on purge flow.
	Mounts break due to vibration	X_1		X_2		X_3							When pressure drops to 20.7KPa (3.0 psi)	Note: Design and development testing should be such that this failure mode has insignificant probability. If it did occur, O_2 and H_2O external leakage might follow requiring abort on purge flow.
	Leak, transport water, external (sublimator or adjacent lines)						X					Gas and LCG feel hot, unless leak seals with an ice dam.	Five minutes after feeling hot.	Abort on purge flow.
	O_2 Line from Tank to TCS													
	External leak	X_1		X_2		X_3							When pressure drops to 20.7KPa (3.0 psi).	Abort on regulated flow.

Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Water Reservoir and Bladder													
	Tank O_2 leak or line O_2 leak	X_1		X_2		X_3							When pressure drops to 20.7 KPa (3.0 psi).	Abort on regulated flow
	Tank H_2O leak or adjacent line H_2O leak						X					Gas and LCG feel hot after feedwater is exhausted through the leak.	Five minutes after feeling hot	Abort on purge flow
	Bladder leak													
	a. during charging											Floods air circuit until gas pressure reaches water charging pressure. Water would be blown to helmet area (before donning helmet) when fan is started. Bladder may not be fully extended, and water may not be available.	Will be detected before egress.	Scrub EVA mission. TCS of no further use until repair is accomplished.
	b. during EVA						X					Unavailability of part of the water. Gas and LCG feel hot after feedwater no longer feeds to sublimator.	Five minutes after feeling hot.	Abort on purge flow. (Not likely, as gas loop pressure is equal to or greater than water pressure)
	Bladder failure to fill full, due to sticking or kinking.						X					Gas and LCG feel hot when the water is prematurely exhausted.	Five minutes after feeling hot.	Abort on purge flow
	Gas outlet plugged by bladder													Prevented by design.
	Water freezes													Prevented by design, thermal analysis
	Overpressure													Prevented by relief valve
	Expansion Tank and Bladder													
	Tank O_2 Leak	X_1		X_2		X_3							When pressure drops to 20.7KPa (3.0 psi).	Abort on regulated flow
	Tank H_2O leak or leak in adjacent H_2O line						X					Air and LCG feel hot after feedwater is exhausted through the leak	Five minutes after feeling hot	Abort on purge flow

Item	Name and Failure Mode	O_2 Tank. Press. Hi Use or Lo Use Press.	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Expansion Tank and Bladder (Cont'd)													
	Bladder leak during draining and after opening tank to tank valve. Also during EVA.											No symptoms during draining. Could prevent complete water expulsion and allow water to migrate outside the bladder. This could result in blowing water into the oxygen lines when tank-to-tank valve is opened after the reservoir is filled. This water might be blown into the helmet area upon starting the fan, or subsequently. Also, water trapped outside the bladder may be unavailable as feed water. Thus, there may be two effects. One is premature water unavailability, and the other is slugs of water blown into the helmet area. The slurper may be effective in removing water.	Five minutes after feeling hot	A transient slug of water to the helmet area prior to donning the helmet is not a sufficient evidence, since there are other reasons why such could happen. Abort on purge flow (Not likely as O_2 pressure always equal to or greater than H_2O pressure)
	Bladder failure to collapse during draining													Prevented by design
	Bladder failure to fill, due to sticking or kinking											If this were extensive, sublimator breakthrough would be observed upon turning on the sublimator	NA	If breakthrough occurs, scrub the EVA mission
	Water freezes													Prevented by design
	Overpressure													Prevented by relief and check valve
	Relief Valve and Check (Expansion Tank)													
	Fails to check													Same analysis as for water valve internal leak
	Fails to relieve													This is a very unlikely failure mode and would represent a second failure

Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Sumptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Relief Valve and Check (Expansion Tank) (Cont'd)													
	External leak													Same analysis as for water valve external leak.
	Relief Valve and Check (Main Reservoir)													
	Fails to relieve											Allows tank and entire water transport loop to become overpressurized in event of temperature increase after filling, and before starting the sublimator.	Hours or minutes at elevated temperature.	The relief valve should be checked for proper operation before each Shuttle mission. Note: Resilience of tubing in transport water loop is sufficient to absorb a certain amount of volume increase without dangerous pressure rise.
	Fails to check											No effect		
	Internal leak at less than relief pressure of 50 psi.						X					Crew observation of water escaping through the porous plate, prior to egress. If not noticed then it would be detected when gas and LCG feel hot.	Five minutes after feeling hot.	Continue the EVA mission but shorten it to account for loss of water.
	External leak													
	a. upstream of seat						X					Crew observation before turning on sublimator. If not noticed, then it would be detected when gas and LCG feel hot, unless leak seals with an ice dam.	Five minutes after feeling hot.	Abort on purge flow
	b. downstream of seat						X					Crew observation when sublimator is turned on. If not noticed then, it would be detected when gas and LCG feel hot unless leak seals with an ice dam.	Five minutes after feeling hot.	Abort on purge flow.

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Item	Name and Failure Mode	O_2 Tank Press. Hi Use or Lo Use Press.	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Check Valve (feedwater replenishment of transport water)													
	Fails to open						X					LCG feels hot due to lack of circulation. Gradual loss of transport water through the gas separator would not be replenished and the pump would cavitate.	20-30 Minutes	Abort on regulated flow.
	Fails to check											No significant effect unless there is a leak in the feedwater system, in which case the fluid would also be lost from the transport loop, and eventually oxygen would be lost through reverse flow in the gas separator.	NA	No action necessary for single failure. For double failure, which would be signalled by a high use of O_2, abort on purge flow. Oxygen might be conserved by shutting off the gas separator valve.
	External leak						X					Crew observation when charging the TCS with water. If not noticed then it would be detected when gas and LCG feel hot.	Five minutes after feeling hot.	Abort on purge flow.
	Gas Separator													
	Gas breaks through screen, or screeen seals leak.						X					Pump may cavitate. Loss of liquid flow. LCG feels hot.	20-30 minutes	Abort on purge flow (for cooling effect). Note: The system tolerates a moderate amount of gas breakthrough, which can be caught and separated in the next time around the loop.
	Screen clogs						X		X			Pump dead-headed. Loss of liquid flow. LCG feels hot.	20-30 minutes	Abort on purge flow (for cooling effect)
	Orifices clog						X					Gas will not be separated. Pump may cavitate. Loss of liquid flow. LCG feels hot.	20-30 minutes	Abort on purge flow (for cooling effect) Note: There are four orifices, each 8×10^{-6}m (0.013") diameter in parallel flow. Only one is required in zero-g.
	External leak of separator or adjacent lines.						X					Loss of water. Gas and LCG become hot after feedwater is exhausted through the leak.	Five minutes after feeling hot.	Abort on purge flow.

Item	Name and Failure Mode	Press. Hi Use or Lo Use Press.	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Water Pump, Item 13													
	Inverter failure due to a short, an open, unexpected circuit dynamics, or failed electronic parts or electrical connector						X					LCG feels hot	Five minutes after feeling hot	Abort on purge flow (fo. cooling effect).
	Torque motor failure due to contamination, electrical open or short, mechanical failure of armature or torque tube, or loosening.						X					Reduce or stopped flow. LCG feels hot.	Same as above	Same as above
	An inlet check valve fails open or closed						X					Flow rate is cut in half. LCG may feel hot.	Indefinite	May be able to continue mission at reduced activity. Otherwise, abort. If body temperature has risen, abort on purge flow Otherwise, the abort could be carried out on the TCS.
	An outlet check valve fails closed						X					Overpressure could destroy the adjacent diaphragm. (or stop the pump). After flooding the motor interior, the second diaphragm could become damaged, causing loss of flow. LCG feels hot.	20-30 minutes	Abort on purge flow, for additional cooling.
	An outlet check valve fails open.						X					Pump flow would recirculate within the pump, resulting in little or no output flow. LCG feels hot.	20-30 minutes	Abort on purge flow, for additional cooling.
	Diaphragm leaks						X					The pump continues to operate. The motor cavity fills with water and it leaks from the motor casing, losing water. If the leak is large, the water could be exhausted prematurely and the gas and LCG would feel hot.	Five minutes after feeling hot.	Abort on purge flow.

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Item	Name and Failure Mode	O2 Tank Pressure Hi	O2 Tank Pressure Lo	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	Water Pump Item 13 (Cont'd)														
	External leak, pump or adjacent lines							X					The pump continues to operate. The motor cavity fills with water and it leaks from the motor casing losing water. If the leak is large, the water could be exhausted prematurely and the gas and LCG would feel hot.	Five minutes after feeling hot.	Abort on purge flow
	Mounts fail							X					This could leak to cracked tubes and loss of water. Analysis same as above.	Same as above.	Same as above.
	Trapped gas								X				Decreased flow rate. LCG may feel hot.	Indefinite	Abort on purge flow, for additional cooling.
	Pump turned off by mistake.							X					LCG feels hot.	About 2 minutes	Turn on pump.
	O_2 Pressure Sensor, PGA														
	Drifts high			X									The only effect on the system would be the apparent symptom of abnormally high pressure suggesting an O_2 regulator failure. If the suit wrist gage indicates normal pressure and the suit relief valve does not open, the pressure gage would be suspected of failure.	Note: Even if true, the suit relief valve should prevent catastrophic overpressure.	Since the failure may indicate an inability of instrumentation to warn of low pressure, a decision would probably be made to abort.
	Drifts low				X								Apparent low pressure suggesting either a failed closed regulator or a gross suit leak.	When pressure reaches 20.7 KPa (3.0 psi).	Abort on purge flow when apparent pressure reaches a selected low level between 20.7 KPa (3.0 psi) and 23 KPa (3.5 psi) since a true reading might not allow time for fault isolation.
	Zero Output				X								See Corrective Action		The transducer design may be such that zero pressure produces a sensor output. In this case a zero output would announce a sensor or conditioner failure. Otherwise, this case would be the same as for "drifts low".

Item	Name and Failure Mode	O_2 Tank Pressure Hi	O_2 Tank Pressure Lo	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	O_2 Pressure Sensor, PGA (Cont'd)														
	Full scale output			X									See corrective action		The transducer design may be such that infinite pressure would create a maximum finite output. In this case, a full scale output would announce a sensor or conditioner failure. Otherwise, this case would be the same as for "drifts high".
	CO_2 Sensor														
	Drifts high						X							See Corrective action	If the apparent CO_2 partial pressure rises to 15 mm, abort should be initiated, eventhough this might be a false alarm.
	Drifts low													See Corrective action	An abnormally low CO_2 reading in itself suggests possibility of instrument failure, depending somewhat on the location of the sensor. The most important place to measure CO_2 partial pressure is at the point of crew inhalation. The sensor offers maximum protection at this point, giving the overall effect of ventilation and CO_2 absorption. The response of the instrument may be checked by shutting off the fan for 30 seconds. If the apparent CO_2 level rises, the value reached could be employed as a new limit. If the instrument does not respond, an abort decision would be made.
	Zero output														An abort decision would be made.
	Full scale output						X							Seconds, if value were true	Abort on purge flow.
	O_2 Tank Pressure Sensor														
	Drifts high	X											Increasing pressure when it should be decreasing suggests failed sensor.	NA	Response if sensor to decreasing pressure may be checked by opening the purge valve briefly. Note: Other components shield the O_2 tank and prevent large pressure increase even though thermal shield is damaged.

Item	Name and Failure Mode	O_2 Tank Pressure Hi	O_2 Tank Pressure Lo	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	O_2 Tank Pressure Sensor (Cont'd)														
	Drifts high (Cont'd)												A gradual drift not quite offsetting a true decrease of pressure could result in O_2 exhaustion without detection until PGA pressure began to be involved. However, this would require double failure.	When PGA pressure is down to 20.7 KPa (3.0 psi).	Abort on purge flow. Mission should receive intensive monitoring if extended beyond expected O_2 supply period.
	Drifts low		X										Falsely indicates higher than normal rate of O_2 usage, suggesting a leak.	If a true value, when PGA pressure is down to 20.7 KPa(3.0 psi).	Abort on purge flow.
	Zero output												Falsely suggests massive loss of O_2.		Same as for O_2 pressure sensor, PGA.
	Full scale output												Falsely indicates extreme pressure increase.		Same as for O_2 pressure sensor, PGA or same as for "drifts high".
	O_2 Ventilation Flow Sensor														
	Drifts high												Depending on location of sensor, a high reading could falsely indicate an external leak.	If value were true, time could be in seconds.	Abort on purge flow.
	Drifts low					X							Falsely suggests a failure of air circulation.	If value were true, may be less than one minute.	Abort on purge flow.
	Zero output					X							This falsely suggests failed fan or clogged loop.	Same as above.	Same as for O_2 pressure sensor, PGA. If zero output can possibly mean zero flow, abort on purge flow.
	Full scale output												This falsely suggests a massive external leak.	If value were true, seconds.	Abort on purge flow.
	H_2O Temperature Sensor														
	Drifts high							X					This falsely suggests failure of sublimator, due to lack of water, etc.	Indefinite	The temperature sensor normally supplies advance warning of exhaustion of feedwater before the LCG and gas feels hot to the astronaut. Either an abort can be initiated or a watching period entered to determine if the high temperature becomes "real".

Item	Name and Failure Mode	O_2 Tank Pressure Hi	O_2 Tank Pressure Lo	PGA Press. Hi	PGA Press. Lo	Vent Flow Lo	CO_2 Press. Hi	H_2O Temp. Hi	H_2O Temp. Lo	Batt. Current Hi	Batt. Current Lo	Batt. Volts Lo	Other Symptoms and/or Effects	Time to Emerg. Level	Corrective Actions
	H_2O Temperature Sensor (Cont'd)														
	Drifts low								X				This falsely suggests lack of transport water flow. In start-up it could indicate sublimator action when none had occurred.	Indefinite	The mission may continue under more frequent monitoring.
	Zero Output								X				See corrective action		Same as for O_2 pressure sensor, PGA, or if zero output can possibly mean extremely low temperature, the mission could continue with minute-to-minute monitoring until the instrument failure was evident.
	Full scale output							X					See corrective action		Same as for O_2 pressure sensor, PGA or same as for "drifts high".
	Battery Current Sensor														
	One of the two resistance elements fails "open".									X			Apparent doubling of normal current, while voltage remains normal.	Indefinite	Monitor voltage as a function of time. If voltage trace behaves normally, the failure of the current sensor would be indicated. Note that if both resistance elements open, a complete loss of power would occur. Current would go to zero, while voltage remained high. Warnings would be deactivated. High voltage and "no-current" should thus be arranged to cause a warning, as well as low voltage alone.
	One of the resistance elements shorts to the other.										X		Apparent low current while voltage and other functions are normal.	NA	Increase frequency of monitoring, and prepare for abort if any evidence of performance loss appears.
	Voltage Sensor														
	Falsely indicates low voltage.											X			Abort on purge flow.
	Fails to indicate low voltage.														If battery current sensor has indicated normal currents, but voltage trace does not decrease near end of mission, voltage sensor would be suspected and mission would be terminated early, to ensure that power is not lost.
	Smoke, smell, vomit, water globules in air stream, etc.												Crew observation		Abort on purge flow. Shut off fan and pump.

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TABLE 3
TENTATIVE CHECK OUT, CHARGE, AND START UP LIST

TCS Sequence for Check Out (Before Charging)
- Check that dump valve is closed
- Check that O_2 regulator is off
- Check that gas separator outlet valve is closed
- Check that the canister is fresh
- Check that pump is "off"
- Check that fan is "off"
- Connect and lock battery cable

TCS Sequence for Charging
- Close feed water valve
- Open valve between tanks
- Connect drain to the drain line
- Turn on O_2 valve-pressure regulates 4 psi above ambient
- Close valve between tanks after a specified time
- Disconnect drain
- Turn off O_2 valve
- Connect fill to fill line
- Open dump valve to allow gas to escape
- Close dump after specified lapse of time
- Disconnect fill
- Open valve between tanks to allow pressure balance

TCS Sequence for Start Up
- Enter pressurized airlock
- Don suit without helmet
  - Connect O_2 to and from PGA
  - Connect LCG
- Don backpack
- Connect vehicle water umbilical
- Turn on pump and feel cool flow
- Attach vehicle O_2 recharge line
- Turn on fan and feel the flow
- Open gas separator valve
- Don gloves
- Don helmet
- Turn on O_2 regulator
- Open suit purge valve
- After a specified purging time, close suit purge valve
- Disconnect vehicle recharge O_2 line
- Conduct pressure integrity check
- Depressurize airlock
- Disconnect water umbilical
- Check airlock pressure
- Open feed water valve to start sublimator

TABLE 3
(Continued)

Check all instruments, warning flags, and telemetry
Verify O_2 total pressure
Verify CO_2 partial pressure
Verify H_2O temperature
Verify battery current and voltage
Verify O_2 is "on"
Adjust to achieve comfort

HAMILTON STANDARD Division of UNITED TECHNOLOGIES

APPENDIX C

SUBSYSTEMS AND SYSTEM DEVELOPMENT TEST PLANS

EVLSS

THERMAL CONTROL SYSTEM

HEAT REJECTION SUBSYSTEM

DEVELOPMENT TEST PLAN AND PROCEDURE

TCS-1

PREPARED BY: W Borchelle DATE: 6-28-74

APPROVED BY: F. Goodwin DATE: 7-24-74
ENGINEERING PROGRAM MANAGER

APPROVED BY: R.C. Woodruff DATE: 7-3-74
QUALITY ASSURANCE

APPROVED BY: Michael Rouen DATE: 6-18-75
NASA

1.0 INTRODUCTION

1.1 Purpose

This test plan and procedure defines the Thermal Control System Heat Rejection Subsystem (HRS) development test program.

1.2 Scope

This document outlines and describes the item to be tested, test conditions and objectives and performance criteria. The results of this test program will be included in the monthly progress reports.

1.3 Description of Test Item

The test item is the Thermal Control System Heat Rejection Subsystem which is defined schematically in Figure 1. The test unit is defined by drawing SVSK 87320.

2.0 APPLICABLE DOCUMENTS

Drawings

SVSK 87320	Sublimator - Assembly and Details

Standards

MIL-O-27210	Oxygen Aviators Breathing, Liquid and Gas
MIL-P-27401	Propellant, Pressurizing Agent, Nitrogen

Specifications

NASA

MSC-SPEC-C21	Water, High Purity (Potable) Specification for

Hamilton Standard

HS 1550	Pre Acceptance, Cleaning, Preservation and Handling of Products
SVP 114	Test Fluid Control (High Purity Water)

3.0 TEST SEQUENCE

Sequence	Test	Test Number
1	Examination of Product	5.1
2	Proof Pressure Test	5.2
3	Leakage Test	5.3
4	Steady State Test	5.4.2
5	Mission Test (Venting)	5.4.3
6	Mission Test (Non Venting)	5.4.4
7	OFF Design Test	5.4.5
8	Service	5.5
9	Weight	5.6
10	Mission Test (Venting)	5.4.3
11	Mission Test (Non Venting)	5.4.4
12	Leakage Test	5.3
13	Examination of Product	5.1

4.0 SPECIAL INSTRUCTIONS

4.1 Rigor

The test program shall be conducted under the direction of the cognizant project engineer. Hamilton Standard inspection shall be on a surveillance basis only. Any changes to the approved test plan will be coordinated with NASA.

4.2 Reporting

The results of the test program will be included in the monthly progress reports.

4.3 Control of the Test Item

It shall be the responsibility of the project engineer to insure that the historical log sheets reflect all operations performed on the test article during the test program.

4.4 Equipment Logs (Test Logs)

The test operator shall obtain sufficient data to verify that the test conditions and environmental conditions have been controlled as specified herein. This log will be maintained by the test operator(s). In general, the log shall include, but not be limited to, the following data:

a. Test Title and Procedure Section Number
b. Date
c. Environmental Conditions
d. Test Operator
e. Test Equipment
f. Notes and Comments
g. Test Results

Sample Log Sheets are included in Section 6.

4.5 Environmental Requirements

Unless otherwise specified, testing shall be conducted at local Ambient Temperatures and Barometric Pressure. Correction shall be made to provide agreement with the temperature and pressure calibration of the instruments.

4.6 Cleanliness Requirements

Nitrogen conforming to MIL-P-27401 and oxygen conforming to MIL-O-27210 shall be used during testing specified within this document. This gas shall be filtered through a 15 micron absolute filter. The water used during these tests shall be distilled and demineralized per MSC-SPEC-C21 with the following exceptions:

4.6 (Continued)

1. The water shall contain silver bromide at a concentration of 50-100 ppb.

2. Total solids shall be 3.5 mm/liter maximum.

3. The particulate contamination shall be as follows:

Particle Size Range (Microns)	Maximum Number of Particles Per 100 ML
0-25	Unlimited
25-50	2,100
50-100	100
100-250	4
250	0

Fibers	Maximum Number of Particles Per 100 ML
100-250	1
250-400	1
400	0

4. The PH range shall be 5.5 to 7.5 at 25°C.

5. The following subparagraphs of MSC-SPEC-C21 are not applicable:

   a. 4.1

   b. 4.1.3

   c. 4.1.6

   d. 4.1.7

   e. 4.1.8

   f. 4.1.10

The external surfaces of the test article shall be maintained to a cleanliness level of HS 1550C1.

NOTE: Water cleaned per SVP 114 meets the requirements above.

5.0 DEVELOPMENT TESTS

5.1 Examination of Product (Log Sheet 6.1)

The item will be examined with respect to surface finish, coating, visual defects and compliance with drawing SVSK 87320. The unit will not be disassembled to do a visual examination. Any visual degradation of unit will be recorded during the test program.

5.2 Proof Pressure (Log Sheet 6.2)

5.2.1 Gas Circuit

The unit shall be set up as shown in Figure 2, and the gas circuit shall be pressurized with nitrogen to a pressure of 6.0 psig. This pressure shall be maintained for five minutes. There shall be no permanent deformation as a result of this test.

5.2.2 Liquid Circuit

The unit shall be set up as shown in Figure 2, and the liquid circuit shall be pressurized with nitrogen to a pressure of 54 psig. This pressure shall be maintained for five minutes. There shall be no permanent deformation as a result of this test.

5.3 Leakage Test (Log Sheet 6.3)

5.3.1 Gas Circuit

The unit shall be set up as shown in Figure 3, and the gas circuit shall be pressurized with nitrogen to a pressure of 4.0 psig, and the unit will be submerged in water for 15 to 20 minutes. There shall be no evidence of gas leakage.

5.3.2 Liquid Circuit

The unit shall be set up as shown in Figure 3, and the liquid circuit shall be pressurized with nitrogen to a pressure of 36 psig, and the unit will be submerged in water for 15 to 20 minutes. There shall be no evidence of gas leakage. This test may be combined with 5.3.1. After this test, the unit shall be dried for one hour at a temperature of 130°F and a pressure of 2 psia maximum.

5.4 Performance Testing

5.4.1 General

The HRS shall be set up as shown in Figure 4, and the following parameters shall be observed and recorded at the intervals specified for the individual tests.

a. Gas Circuit

P_{out}, P_{in}, Delta P, T_{in}, T_{out}, Delta T, T_{DPin}, T_{DPout}, Flow

b. Liquid Circuit

P_{in}, Delta P, T_{in}, T_{out}, Delta T, Flow

c. Feedwater Circuit

P_{in}, T_{in}, Flow

d. Slurper

Delta P, Gas Flow, Water Flow.

5.4.2 Steady State Tests (Log Sheet 6.4)

The gas circuit and liquid circuit and feedwater conditions will be set as specified in Table I, and the feedwater flow shall be initiated. The times from flow initiation until the liquid loop temperature starts to

5.4.2 (Continued)

drop and until liquid loop and gas loop temperature stabilization shall be recorded. The liquid loop temperature shall be below 45°F within 10 minutes. The condition of the porous plate during start up shall be observed and reported.

The gas circuit and liquid circuit conditions shall be stabilized for at least 15 minutes at each steady state condition specified in Table I, and the required data will be recorded. The unit shall meet the performance requirements specified in Table I. At each steady state condition, a small amount of air (approximately 2 cc) will be introduced in the feed-water line. The unit must continue to operate after the introduction of the air.

With the heat load set as specified in Table I, the feedwater will be shut off. The unit must be non venting within five minutes.

The entire test will be repeated using the conditions and requirements specified in Table II.

5.4.3 Mission Test (Venting) (Log Sheet 6.4)

The gas circuit, feedwater circuit and liquid circuit conditions will be set as specified in Table III, and the feedwater flow will be initiated. The gas circuit and liquid circuit conditions will be varied in accordance with Figure 5. After two hours of operation, the feedwater will be shut off for one half hour and then shall be restarted. After 1.5 hours of additional operation, the unit will be shutdown. The unit will meet the requirements defined in Table III. The data will be recorded at each change in condition. This test shall be repeated four additional times, except the one half hour shutdown will be deleted. The ambient pressure will be returned to room pressure between tests.

5.4.4 Mission Test (Non Venting) (Log Sheet 6.5)

The gas circuit and liquid circuit inlet conditions shall be set as specified in Table IV. The conditions will be varied in accordance with Figure 6. The data shall be recorded at each change in condition.

5.4.5 OFF Design Tests (Log Sheet 6.4)

The feedwater circuit will be wetted at room pressure and then the ambient pressure will be reduced to vacuum. The start up conditions specified in Table I will be established, and the feedwater flow will be initiated. The condition of the plate will be observed and reported. The data will be recorded every five minutes for one half hour. The vent flow will be increased to 7.1 - 7.2 ACFM, and performance will be observed for one hour after which the flow will be increased to 10.0 - 10.2 ACFM, and performance will be observed for an additional hour.

The flow will be reset at 5.5 - 5.8 ACFM, and the liquid loop inlet temperature will be increased in five degree increments until break-through occurs or until the outlet temperature exceeds 100°F.

The unit will be returned to ambient conditions. The porous plate will be removed, the seal will be cut 50% through on its upper face, and the plate will be replaced. The start up condition specified in Table II will be established, and the feedwater flow will be initiated. The unit will be stabilized at each point specified in Table II.

5.5 Service (Log Sheet 6.6)

The porous plate will be removed from the sublimator, and its condition will be reported. A new plate will then be installed in the unit. Also, the nicked seal will be repaired or replaced.

5.6 Weight (Log Sheet 6.7)

After service, the weight of the unit will be determined with the unit dry and the liquid circuit full of water.

TABLE I

STEADY STATE TEST - ROOM TEMPERATURE START

INITIAL CONDITIONS

Liquid Loop:	Flow 240 ± Lb/Hr, T_{in} 50°F Min, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	T_{in} 72°F Min, T_{DPin} 50°F Min, Flow 5.5-5.8 ACFM, Inlet Pressure 3.85 ± .15 Psia
Feedwater Circuit:	T_{in} 70° ± 15°F, Inlet Pressure 3.7-4.0 Psia Feedwater Valve Closed
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 ± 15°F, Pressure 1,000 μ Maximum

STEADY STATE CONDITIONS

Low Load

Liquid Loop:	Flow 240 ± 5 Lb/Hr, ΔT 1°F, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	A) Flow 5.5-5.8 ACFM, T_{in} 72°F ± 2°F, T_{DPin} 35-37°F, Inlet Pressure 3.85 ± .15 Psia
	B) Flow 5.5-5.8 ACFM, T_{in} 90 ± 2°F, T_{DPin} 65 ± 5°F, Inlet Pressure 3.85 ± .15 Psia
	C) Flow 5.5-5.8 ACFM, T_{in} 110°F ± 2°F, T_{DPin} 91 ± 2°F, Inlet Pressure 3.85 ± .15 Psia
Feedwater Circuit:	T_{in} 70° ± 15°F, Inlet Pressure 3.7-4.0 Psia Feedwater Valve Open
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70° ± 15°F, Pressure 1,000 μ Maximum

Nominal Load

Liquid Loop:	Flow 240 ± 5 Lb/Hr, ΔT 5°F, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	A) Flow 5.5-5.8 ACFM, T_{in} 72°F ± 2°F, T_{DPin} 35-37°F, Inlet Pressure 3.85 ± .15 Psia
	B) Flow 5.5-5.8 ACFM, T_{in} 90 ± 2°F, T_{DPin} 65 ± 5°F, Inlet Pressure 3.85 ± .15 Psia
	C) Flow 5.5-5.8 ACFM, T_{in} 110°F ± 2°F, T_{DPin} 91 ± 2°F, Inlet Pressure 3.85 + .15 Psia

TABLE I
(Continued)

Feedwater Circuit:	T_{in} 70 ± 15°F, Inlet Pressure 3.7-4.0 Psia Feedwater Valve Open
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 ± 15°F, Pressure 1,000 μ Maximum
<u>Maximum Load</u>	
Liquid Loop:	Flow 240 ± 5 Lb/Hr, ΔT 10°F, Inlet Pressure 3.5-4.5 Psia
Gas Loop:	A) Flow 5.5-5.8 ACFM, T_{in} 72°F ± 2°F, T_{DPin} 35-37°F, Inlet Pressure 3.85 ± .15 Psia
	B) Flow 5.5-5.8 ACFM, T_{in} 90 ± 2°F, T_{DPin} 65 ± 5°F, Inlet Pressure 3.85 ± .15 Psia
	C) Flow 5.5-5.8 ACFM, T_{in} 110°F ± 2°F, T_{DPin} 91 ± 2°F, Inlet Pressure 3.85 ± .15 Psia
Feedwater Circuit:	T_{in} 70 ± 15°F, Inlet Pressure 3.7-4.0 Psia Feedwater Valve Open
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 ± 15°F, Pressure 1,000 μ Maximum
<u>SHUTDOWN</u>	
Liquid Loop:	Same as Maximum Load
Gas Loop:	Same as Maximum Load
Feedwater Circuit:	Same as Maximum Load Except Feedwater Valve Closed
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 ± 15°F, Pressure 1,000 μ Maximum
<u>REQUIREMENTS</u>	
Start Up:	10 Minutes Max for Liquid Loop $T_{out} < 45°F$
Low Load:	Gas Loop T and $T_{DPout} > 33°F$ and 50°F Max, Delta $P_{gas\ loop}$ 2.8 In H_2O Max, Liquid Loop $T_{out} > 32°F$, Delta $P_{liquid\ loop}$ .728 Psi Max

TABLE I
(Continued)

Nominal Load:	Gas Loop T and T_{DPout} 50°F Max, Delta P_{gas} loop 2.8 In H_2O Max, Liquid Loop T_{out} 45°F Max, Delta P_{liquid} loop .728 Psi Max
Maximum Load:	Gas Loop T and T_{DPout} 50°F Max, Delta P_{gas} loop 2.8 In H_2O Max, Liquid Loop T_{out} 45°F Max, Delta P_{liquid} loop .728 Psi Max
Shutdown:	Five Minutes Maximum to Non Venting

TABLE II

STEADY STATE TEST - HIGH TEMPERATURE START

INITIAL CONDITIONS

Liquid Loop:	Flow 240 ± 5 Lb/Hr, T_{in} 54°F Min, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	Flow 5.5-5.8 ACFM, T_{in} 110°F Min, T_{DPin} 91°F Min, Inlet Pressure 3.85 ± .15 Psia
Feedwater Circuit:	T_{in} 105 ± 5°F, Inlet Pressure 3.7-4.0 Psia Feedwater Valve Closed
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 ± 15°F, Pressure 1,000 μ Maximum

STEADY STATE CONDITIONS

Maximum Load

Liquid Loop:	Flow 240 ± 5 Lb/Hr, ΔT 10°F, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	Flow 5.5-5.8 ACFM, T_{in} 110 ± 2°F, T_{DPin} 91 ± 2°F Inlet Pressure 3.85 ± .15 Psia
Feedwater Circuit:	T_{in} 70 ± 15°F, Inlet Pressure 3.7-4.0 Psia Feedwater Valve Closed
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 ± 15°F, Pressure 1,000 μ Maximum

Nominal Load

Liquid Loop:	Flow 240 ± 5 Lb/Hr, ΔT 5°F, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	Flow 5.5-5.8 ACFM, T_{in} 90 ± 2°F, T_{DPin} 65 ± 5°F Inlet Pressure 3.85 ± .15 Psia
Feedwater Circuit:	T_{in} 70 ± 15°F, Inlet Pressure 3.7-4.0 Psia Feedwater Valve Open
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 ± 15°F, Pressure 1,000 μ Maximum

TABLE II
(Continued)

Low Load	
Liquid Loop:	Flow 240 ± 5 Lb/Hr, ΔT 1°F, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	Flow 5.5-5.8 ACFM, T_{in} 72°F ± 2°F, T_{DPin} 35-37°F, 5 Inlet Pressure 3.85 ± .15 Psia
Feedwater Circuit:	T_{in} 70 ± 15°F, Inlet Pressure 3.7-4.0 Psia Feedwater Valve Open
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 ± 15°F, Pressure 1,000 μ Maximum
SHUTDOWN	
Liquid Loop:	Same as Low Load
Gas Loop:	Same as Low Load
Feedwater Circuit:	Same as Low Load Except Feedwater Valve Closed
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 ± 15°F, Pressure 1,000 μ Maximum
REQUIREMENTS	
Start Up:	10 Minutes Max for Liquid Loop T_{out} $<$45°F
Maximum Load:	Gas Loop T and T_{DPout} 50°F Max, Delta $P_{gas\ loop}$ 2.8 In H_2O Max, Liquid Loop T_{out} 45°F Max, Delta $P_{liquid\ loop}$, .728 Psi Max
Nominal Load:	Gas Loop T and T_{DPout} 50°F Max, Delta $P_{gas\ loop}$ 2.8 In H_2O Max, Liquid Loop T_{out} 45°F Max, Delta $P_{liquid\ loop}$, .728 Psi Max
Low Load:	Gas Loop T and T_{DPout} $>$33°F and 50°F Max, Delta $P_{gas\ loop}$ 2.8 In H_2O Max, Liquid Loop T_{out} $>$32°F, Delta $P_{liquid\ loop}$ .728 Psi Max
Shutdown:	5 Minutes Maximum to Non Venting

TABLE III

MISSION TEST - VENTING

INITIAL CONDITIONS

Liquid Loop:	Flow 240 $\pm$ 5 Lb/Hr, T_{in} 50^{o}F Min, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	T_{in} 72^{o}F Min, T_{DPin} 50^{o}F Min, Flow 5.5-5.8 ACFM, Inlet Pressure 3.85 $\pm$ .15 Psia
Feedwater Circuit:	T_{in} 70^{o} $\pm$ 15^{o}F, Inlet Pressure 3.7-4.0 Psia Feedwater Valve Closed
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 μ Maximum

MISSION SIMULATION

Liquid Loop:	Flow 240 $\pm$ 5 Lb/Hr, Inlet Pressure 3.5-4.0 Psia, ΔT Per Figure 5
Gas Loop:	Flow 5.5-5.8 ACFM, Inlet Pressure 3.85 $\pm$ .15 Psia T_{in} and T_{DPin} Per Figure 5
Feedwater Circuit:	T_{in} 70 $\pm$ 15^{o}F, Inlet Pressure 3.7-4.0 Psia Feedwater Valve Open
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 μ Maximum

SHUTDOWN

Liquid Loop:	Flow 240 $\pm$ 5 Lb/Hr, Inlet Pressure 3.5-4.0 Psia, ΔT Per Figure 5
Gas Loop:	Flow 5.5-5.8 ACFM, Inlet Pressure 3.85 $\pm$ 1.5 Psia T_{in} and T_{DPin} Per Figure 5
Feedwater Circuit:	T_{in} 70 $\pm$ 15^{o}F Inlet Pressure 3.7-4.0 Psia Feedwater Valve Closed
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 μ Maximum

TABLE III
(Continued)

REQUIREMENTS

Start Up:	10 Minutes Max for Liquid Loop $T_{out} > 45^{o}F$
Mission Simulation:	Gas Circuit T and T_{DPout} 32-50^{o}F Delta P 2.8 In H_2O Max Liquid Circuit T_{out} 33-45^{o}F Delta P .728 Psi Max
Shutdown:	5 Minutes Maximum to Non Venting

TABLE IV

MISSION TEST - NON VENTING

INITIAL CONDITION

Liquid Loop:	Flow 240 $\pm$ 5 Lb/Hr, T_{in} 42-45^{o}F, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	Flow 5.5-5.8 ACFM, Inlet Pressure 3.85 $\pm$ .15 Psia, T_{in} and T_{DPin} Per Figure 6
Feedwater Circuit:	Shut Off
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 μ Maximum

MISSION SIMULATION

Liquid Loop:	Flow 240 $\pm$ 5 Lb/Hr, T_{in} 42-45^{o}F, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	Flow 5.5-5.8 ACFM, Inlet Pressure 3.85 $\pm$ .15 Psia, T_{in} and T_{DPin} Per Figure 6
Feedwater Circuit:	Shut Off
Slurper:	Delta P 1-1.5 In H_2O
Ambient:	Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 μ Maximum

REQUIREMENTS

Gas Loop T and T_{DPout} 50^{o}F Maximum

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	Examination of Product
TEST ENGINEER	
NAME OF RIG	Bench
PROJECT & ENG. ORDER NO.	
SHEET OF	DATE
TEST PLAN NO.	TCS-1
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Log Sheet 6.1 Test Number 5.1 Sequence Number

Item conforms to SVSK 87320 Yes No

Itemize Visual Defects

C-20

REMARKS:

Ambient Temperature °F
Barometric Pressure in Hg

71059

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UA

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	Proof Pressure
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	
SHEET OF	
DATE	
TEST PLAN NO.	TCS-1
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Log Sheet 6.2 Test Number 5.2 and 5.2.2 Sequence Number

Clock Time	Test Time Min	Test Pressure Psig	Sequence Number
			5.2.1
			5.2.2

C-21

REMARKS:
Ambient Temperature ^0F
Barometric Pressure in Hg

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LOG OF TEST

TYPE OF TEST: Leakage	SHEET / OF / DATE
TEST ENGINEER	TEST PLAN NO. TCS-1
NAME OF RIG	MODEL NO.
PROJECT & ENG. ORDER NO.	PART NO.
	SERIAL NO.
	OPERATORS

Log Sheet 6.3 Test Number 5.3.1 and 5.3.2 Sequence Number

Clock Time	Test Time Min	Gas Circuit Pressure Psig	Liquid Circuit Pressure Psig	Visual Bubbles Yes	No

REMARKS:
Ambient Temperature °F
Barometric Pressure in Hg
Note: Unit free of surface bubbles before checking for leakage ____ yes ____ no

71057

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LOG OF TEST

TYPE OF TEST	SHEET OF	DATE
TEST ENGINEER	TEST PLAN NO. TCS-1	
NAME OF RIG	MODEL NO.	
PROJECT & ENG. ORDER NO.	PART NO.	
	SERIAL NO.	
	OPERATORS	

Log Sheet 6.4 Test Number Sequence Number

Clock	Test	Gas Circuit										Liquid Circuit							GAS INLET F/K	GAS OUTLET		F/K
Time	Time	P_{in}	P_{out}	ΔP	T_{in}	T_{out}	ΔT	DP_{in}	DP_{out}	Flow		P_{in}	ΔP	T_{in}	T_{out}	ΔT	Flow		P	Flow		P
	Min	Psia	Psia	IN H_2O	°F	°F	°F	°F	°F	%	CFM	Psia	Psi	°F	°F	°F	%	#/Hr	PSIA	%	#/Hr	PsiA

REMARKS:

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WINDSOR LOCKS, CONNECTICUT 06096

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	
SHEET OF	DATE
TEST PLAN NO.	TCS-1
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Log Sheet 6.4 (Continued)

Feedwater Circuit						Slurper						Rig	Header
Pin	Tin	Flow		F/B P	P	ΔP	Gas	Flow	Water		Flow	Pressure	Pressure
Psia	°F	cc/Min		PSIA	PSIA	inH_2O	%	#/Hr	cc	Min	cc/Min	µ	µ

REMARKS:

Ambient Temperature °F
Barometric Pressure in Hg

71055

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LOG OF TEST

TYPE OF TEST: Mission Test Non Venting
TEST ENGINEER:
NAME OF RIG:
PROJECT & ENG. ORDER NO.:

SHEET OF DATE
TEST PLAN NO. TCS-1
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Log Sheet 6.5 Test Number 5.4.4 Sequence Number

Check	Test	Gas Circuit										Liquid Circuit							Rig Leakage	
										Flow							Flow		Flow	
Time	Time	P_{in}	P_{out}	ΔP	T_{in}	T_{out}	ΔT	DP_{in}	DP_{out}			P_{in}	ΔP	T_{in}	T_{out}	ΔT				
	Min	Psia	Psia	Psi	^{o}F	^{o}F	^{o}F	^{o}F	^{o}F	%	CFM	Psia	Psi	^{o}F	^{o}F	^{o}F	%	#/Hr	%	#/Hr

REMARKS:

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	SHEET OF / DATE
TEST ENGINEER	TEST PLAN NO. TCS-1
NAME OF RIG	MODEL NO.
PROJECT & ENG. ORDER NO.	PART NO.
	SERIAL NO.
	OPERATORS

Log Sheet 6.5 (Continued)

									Slurper								Rig					
									ΔP	Gas	Flow	Water		Flow			Pressure					
									inH_2O	%	#/Hr	cc	Min	cc/Min			"					

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REMARKS:

Ambient Temperature ^oF
Barometric Pressure in Hg

71628

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LOG OF TEST

TYPE OF TEST: Service	SHEET OF	DATE
TEST ENGINEER	TEST PLAN NO. TCS-1	
NAME OF RIG	MODEL NO.	
PROJECT & ENG. ORDER NO.	PART NO.	
	SERIAL NO.	
	OPERATORS	

Log Sheet 6.6 Test Number 5.5 Sequence Number

Report Condition of Plate:

C-27

Other Observations:

REMARKS:
Ambient Temperature °F
Barometric Pressure in Hg

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Weight	SHEET OF	DATE
TEST ENGINEER	TEST PLAN NO. TCS-1	
NAME OF RIG	MODEL NO.	
PROJECT & ENG. ORDER NO.	PART NO.	
	SERIAL NO.	
	OPERATORS	

Log Sheet 6.7 Test Number 5.6 Sequence Number

Weight Dry

Weight LCG Loop Filled

C-28

REMARKS:

Ambient Temperature °F
Barometric Pressure in Hg

71689

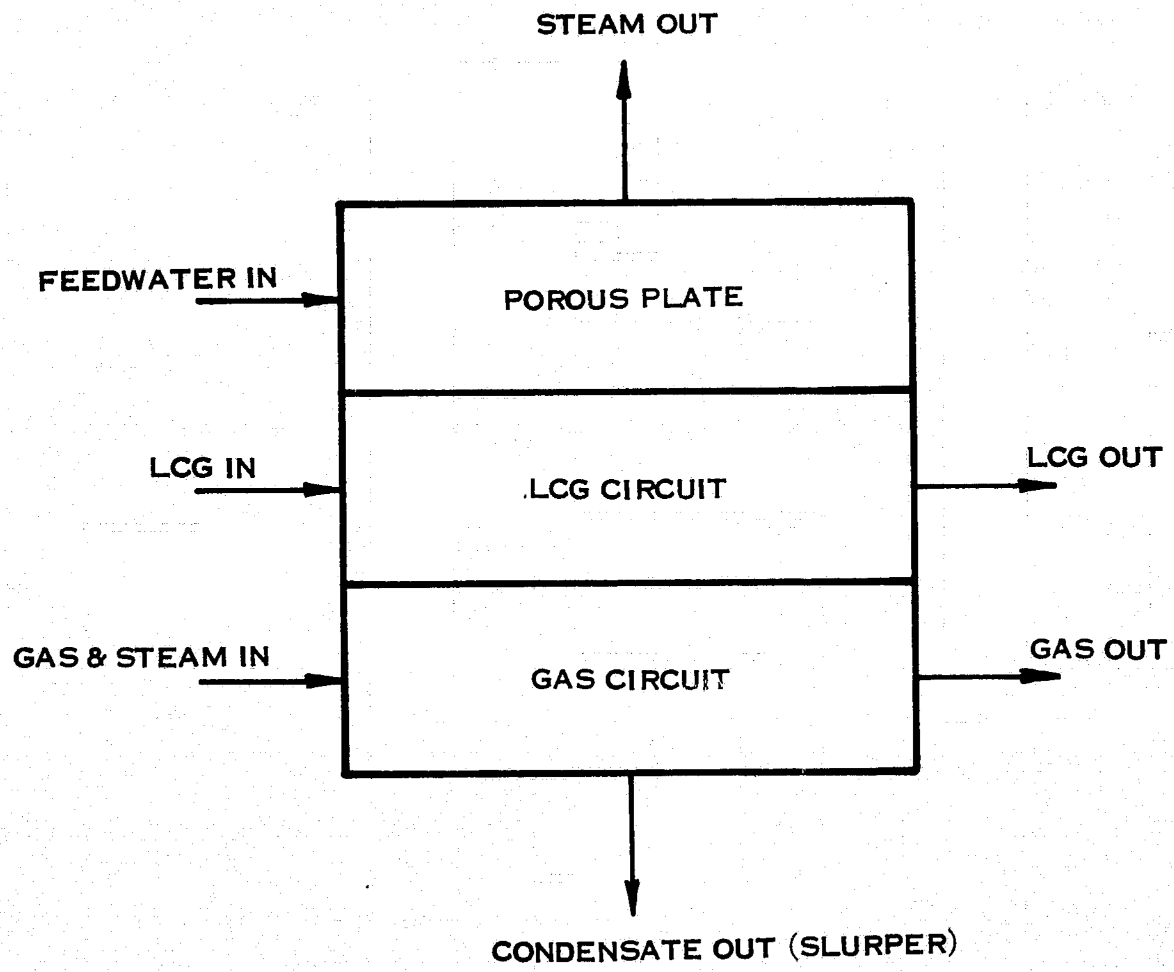

FIGURE 1 HRS SCHEMATIC

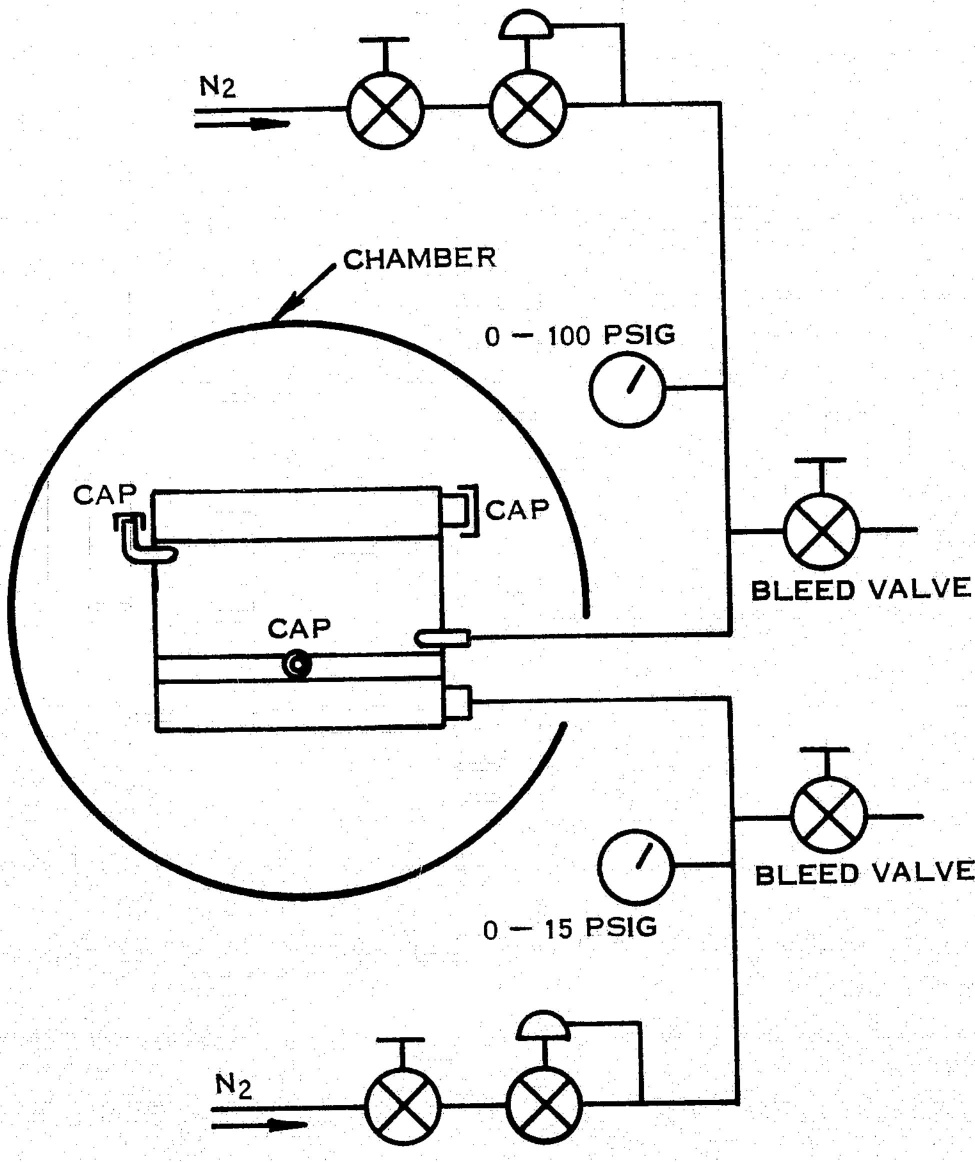

FIGURE 2 PROOF PRESSURE TEST SETUP

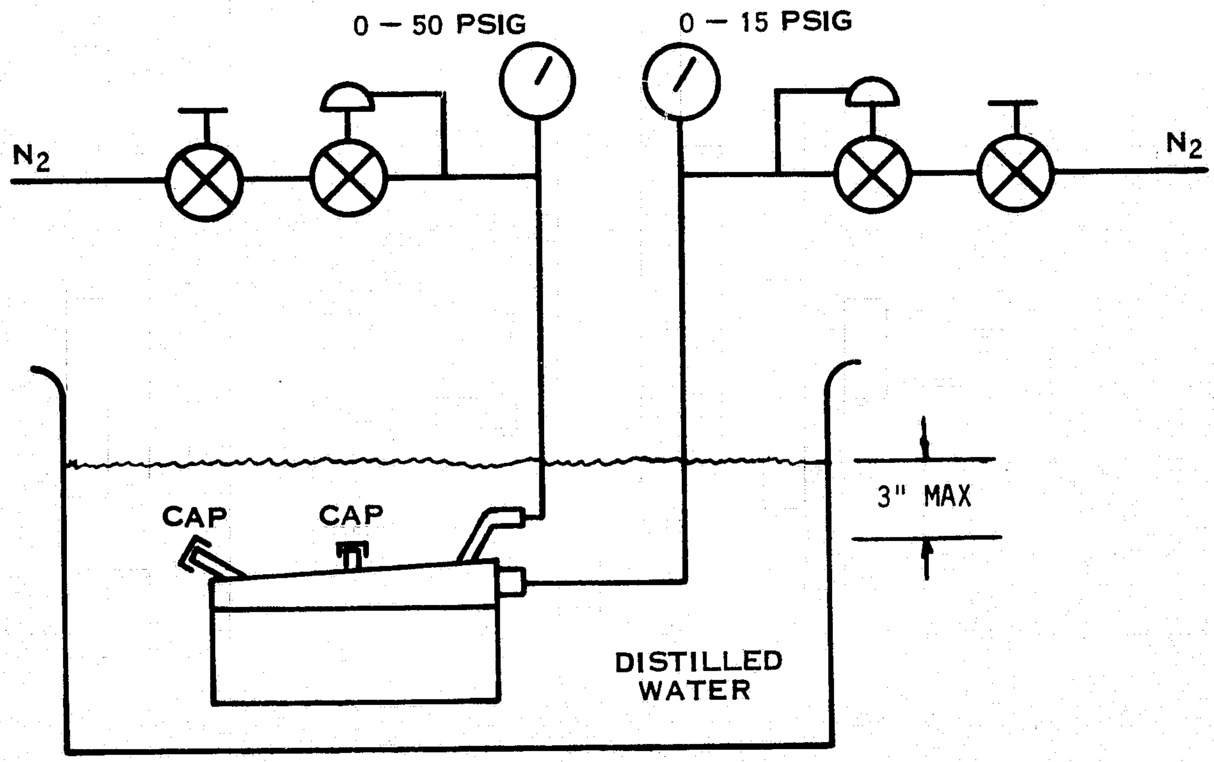

FIGURE 3 LEAKAGE TEST SETUP

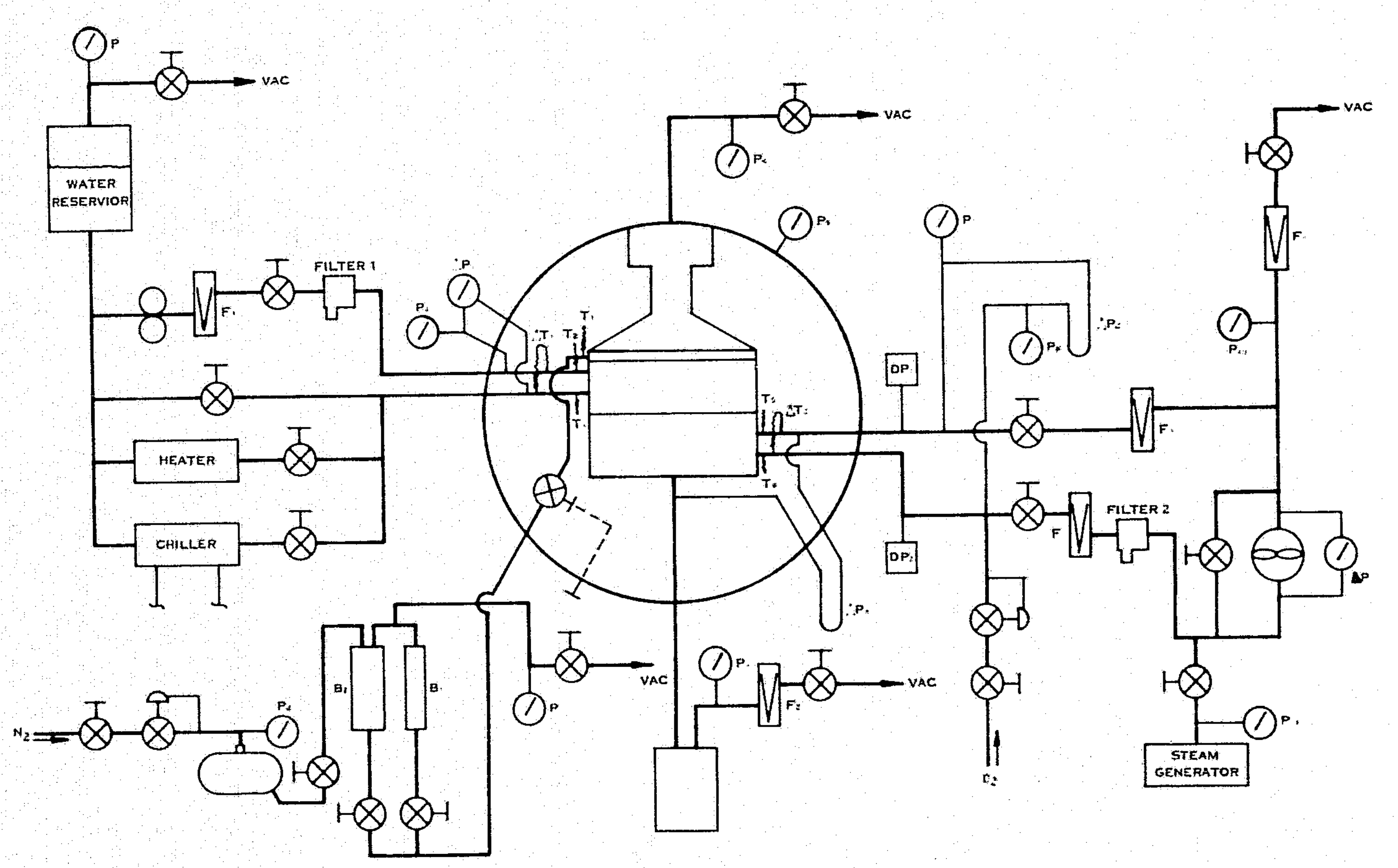

FIGURE 4 PERFORMANCE TEST SETUP

Instrument No.	Parameter	Minimum Range	Minimum Accuracy
P_1	Pump Inlet Pressure	0-30 Psia	$\pm$ 2 Psi
P_2	Feed Water Reservoir Pressure	0-100 Psia	$\pm$ 1 Psi
P_3	Feed Water Inlet Pressure	0-15 Psia	$\pm$ .025 Psi
P_4	LCG Inlet Pressure	0-30 Psia	$\pm$ .3 Psi
P_5	Chamber Pressure	500-1,000 μ	$\pm$ 3% Angular Def
P_6	Steam Header Pressure	500-1,000 μ	$\pm$ 3% Angular Def
P_7	Vent Outlet Pressure	0-15 Psia	$\pm$ .025 Psi
P_8	Vent Inlet Pressure	0-15 Psia	$\pm$ .025 Psi
P_9	Slurper Vacuum Pressure	0-30 Psia	$\pm$ .3 Psi
P_{10}	Leakage Flow Rate Pressure	0-30 Psia	$\pm$ .3 Psi
P_{11}	Steam Generator Pressure	0-30 Psia	$\pm$ .5 Psia
ΔP_1	LCG ΔP	0-10 Psi (Diff)	$\pm$ .1 Psi
ΔP_2	Vent ΔP	0-10 in H_2O (Diff)	$\pm$ .1 in H_2O
ΔP_3	Slurper ΔP	0-10 in H_2O (Diff)	$\pm$ .1 in H_2O
ΔP_4	Fan ΔP	0-100 in H_2O (Diff)	$\pm$ 1.0 in H_2O
F_1	LCG Flow	.6-5.2 PPM	$\pm$ 2% FS
F_2	Slurper Flow	0-5 PPH @ 3.8 Psia	$\pm$ 2% FS
F_3	Vent Inlet Flow	2-12 PPH @ 3.8 Psia	$\pm$ 2% FS
F_4	Vent Outlet Flow	2-12 PPH @ 3.8 Psia	$\pm$ 2% FS
F_5	Rig Leakage Flow	.001-.016 PPH @ 3.5 Psia	$\pm$ 2% FS
T_1	Feed Water Temperature	32-150°F	$\pm$ 3°F
T_2	LCG Inlet Temperature	32-150°F	$\pm$ 3°F
T_3	LCG Outlet Temperature	32-150°F	$\pm$ 3°F
T_4	Vent Inlet Temperature	32-150°F	$\pm$ 3°F
T_5	Vent Outlet Temperature	32-150°F	$\pm$ 3°F
ΔT_1	LCG ΔT	0-20°F	$\pm$ .5°F
ΔT_2	Vent ΔT	0-100°F	$\pm$ 3°F
DP_1	Vent Outlet Dew Point	0-100°F	$\pm$ 3°F
DP_2	Vent Inlet Dew Point	0-100°F	$\pm$ 3°F
B_1	Feed Water Burette (Small)	100 CC	--
B_2	Feed Water Burette (Large)	1,000 CC	--

NO. 340-20 DIETZGEN GRAPH PAPER
20 X 20 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

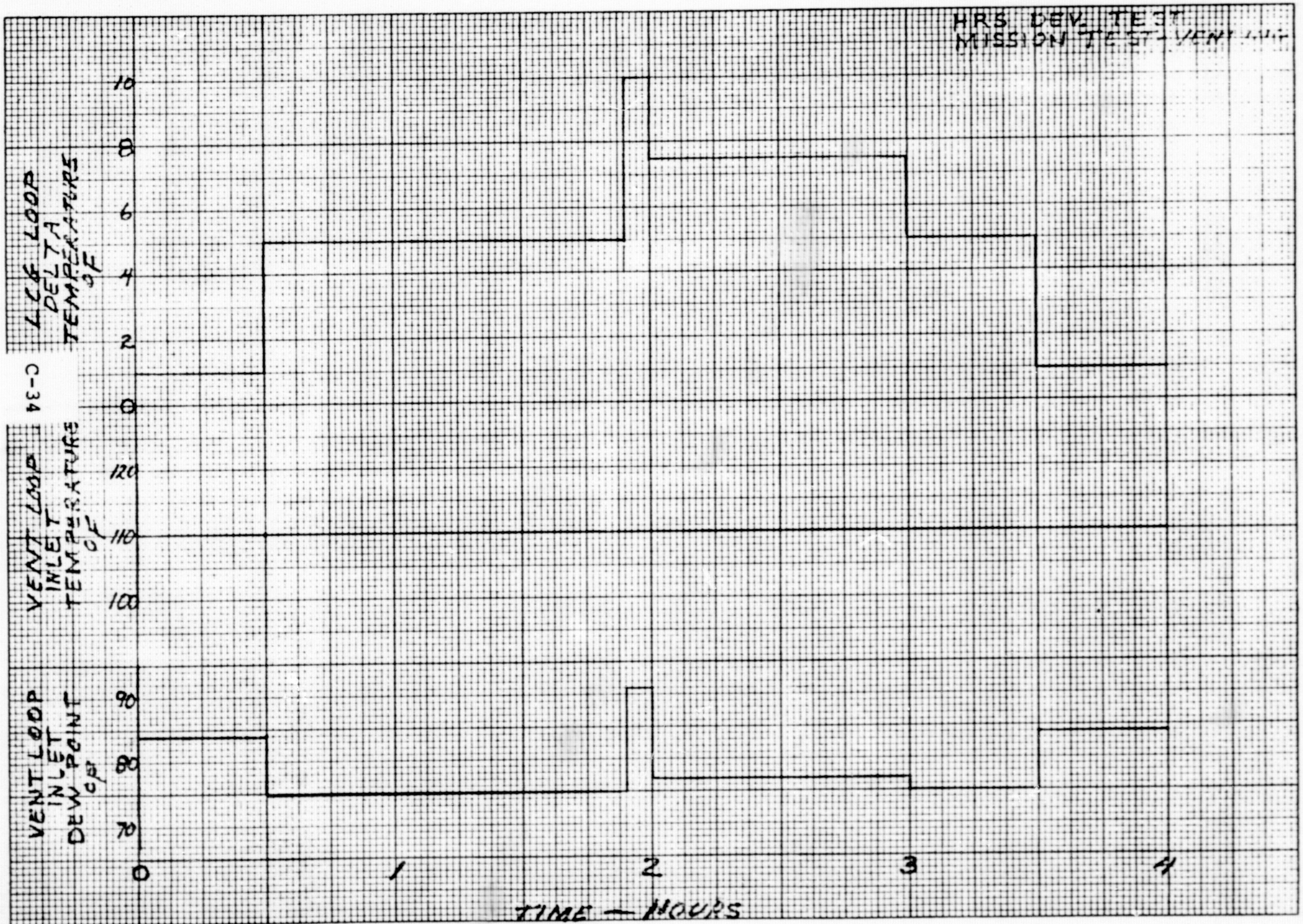

FIGURE 5

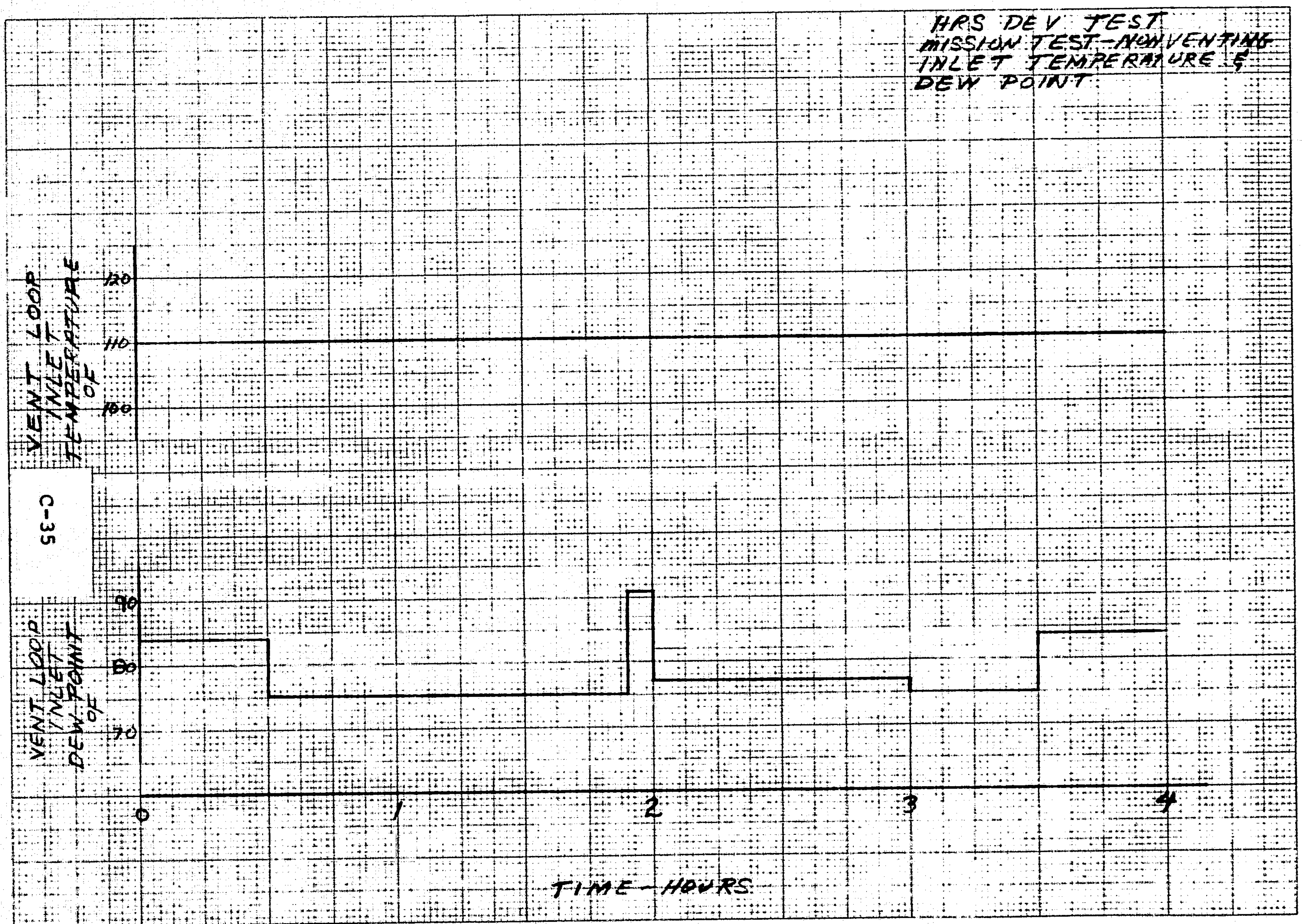
HRS DEV TEST
MISSION TEST-NONVENTING
INLET TEMPERATURE &
DEW POINT
VENT LOOP INLET TEMPERATURE °F
120
110
100
VENT LOOP INLET DEW POINT °F
90
80
70
0
1
2
3
4
TIME-HOURS

FIGURE 6

EVLSS

THERMAL CONTROL SYSTEM

WATER MANAGEMENT SUBSYSTEM

DEVELOPMENT TEST PLAN AND PROCEDURE

TCS-2

PREPARED BY: W Bouchelle DATE: 7-25-74

APPROVED BY: F. Goodwin DATE: 7-26-74
ENGINEERING PROGRAM MANAGER

APPROVED BY: R. Woodruff DATE: 7-26-74
QUALITY ASSURANCE

APPROVED BY: Michael Rouen DATE: 6-18-75
NASA

1.0 INTRODUCTION

1.1 Purpose

This test plan and procedure defines the Thermal Control System Water Management Subsystem (WMS) development test program.

1.2 Scope

This document outlines and describes the item to be tested, test conditions and objectives and performance criteria. The results of this test program will be included in the monthly progress reports.

1.3 Description of Test Item

The test item is the Thermal Control System Water Management Subsystem which is defined schematically in Figure 1. The test unit is defined by drawing SVSK 87319, less details SVSK 87320, SVSK 87343-1, SVSK 87320-78 and SVSK 87319-76.

2.0 APPLICABLE DOCUMENTS

Drawings

SVSK 87319	Thermal Control System
SVSK 87320	Sublimator - Assembly and Details
SVSK 87343	TCS Motor/Rotary Fan Separator

Standards

MIL-O-27210	Oxygen Aviators Breathing, Liquid and Gas
MIL-P-27401	Propellant, Pressurizing Agent, Nitrogen

Specifications

NASA

MSC-SPEC-C21A	Water, High Purity (Potable) Specification for

Hamilton Standard

HS 1550	Pre Acceptance, Cleaning, Preservation and Handling of Products

2.0 (Continued)

SVP 114 Test Fluid Control (High Purity Water)

3.0 TEST SEQUENCE

Sequence	Test	Test Number
1	Examination of Product	5.1
2	Proof Pressure Test	5.2
3	Leakage Test	5.3
4	Check & Relief Valve Performance	5.4
5	Mission Test (Venting)	5.5
6	Mission Test (Non Venting)	5.6
7	Service	5.7
8	Mission Test (Venting)	5.5
9	Mission Test (Non Venting)	5.6
10	Leakage Test	5.3
11	Service	5.7
12	Examination of Product	5.1

4.0 SPECIAL INSTRUCTIONS

4.1 Rigor

The test program shall be conducted under the direction of the cognizant project engineer. Hamilton Standard inspection shall be on a surveillance basis only. Any changes to the approved test plan will be coordinated with NASA.

4.2 Reporting

The results of the test program will be included in the monthly progress reports.

4.3 Control of the Test Plan

It shall be the responsibility of the project engineer to insure that the historical log sheets reflect all operations performed on the test article during the test program.

4.4 Equipment Logs (Test Logs)

The test operator shall obtain sufficient data to verify that the test conditions and environmental conditions have been controlled as specified herein. This log will be maintained by the test operator(s). In general, the log shall include, but not be limited to, the following data:

a. Test Title and Procedure Section Number
b. Date
c. Environmental Conditions
d. Test Operator
e. Test Equipment
f. Notes and Comments
g. Test Results

Sample log sheets are included in Section 6.

4.5 Environmental Requirements

Unless otherwise specified, testing shall be conducted at local Ambient Temperatures and Barometric Pressure. Correction shall be made to provide agreement with the temperature and pressure calibration of the instruments.

4.6 Cleanliness Requirements

Nitrogen conforming to MIL-P-27401 and oxygen conforming to MIL-O-27210 shall be used during testing specified within this document. This gas shall be filtered through a 15 micron absolute filter. The water used during these tests shall be distilled and demineralized per MSC-SPEC-C21 with the following exceptions:

4.6 (Continued)

1. The water shall contain silver bromide at a concentration of 50-100 PPb.
2. Total solids shall be 3.5 mm/liter maximum.
3. The particulate contamination shall be as follows:

Particle Size Range (Microns)	Maximum Number of Particles Per 100 ML
0-25	Unlimited
25-50	2,100
50-100	100
100-250	4
250	0

Fibers	Maximum Number of Particles Per 100 ML
100-250	1
250-400	1
400	0

4. The PH range shall be 5.5 to 7.5 at 25^{o}C.
5. The following subparagraphs of MSC-SPEC-C21 are not applicable:
   a. 4.1
   b. 4.1.3
   c. 4.1.6
   d. 4.1.7
   e. 4.1.8
   f. 4.1.10

The external surfaces of the test article shall be maintained to a cleanliness level of HS 1550C1.

NOTE: Water cleaned per SVP 114 meets the requirements above

5.0 DEVELOPMENT TESTS

5.1 Examination of Product (Log Sheet 6.1)

Examine the item with respect to surface finish, coating, visual defects and compliance with drawing SVSK 87319. Do not disassemble the unit to do a visual examination. Record any visual degradation of unit during the test program. Determine and record the dry weights of the unit.

5.2 Proof Pressure (Log Sheet 6.2)

5.2.1 Gas Circuit

Setup the unit as shown in Figure 2, and pressurize the gas circuit with nitrogen to a pressure of 6.0-6.2 psig. Maintain this pressure for five minutes. There shall be no permanent deformation as a result of this test.

5.2.2 Liquid Circuit

Setup the unit as shown in Figure 2, and pressurize the liquid circuit with nitrogen to a pressure of 54-56 psig. Maintain this pressure for five minutes. There shall be no permanent deformation as a result of this test.

5.3 Leakage Test (Log Sheet 6.3)

5.3.1 Gas Circuit

Setup the unit as shown in Figure 3, and pressurize the gas circuit with nitrogen to a pressure of 4.0-4.2 psig. Set the gas inlet flow as required to maintain the pressure at a constant value and maintain this condition for 15 to 20 minutes. The inlet flow shall not exceed 18 scc/min.

5.3.2 Liquid Circuit (Log Sheet 6.4)

Setup the unit as shown in Figure 4, and pressurize the liquid circuit with water to a pressure of 36 psig for 15 to 20 minutes. There shall be no visible evidence of leakage.

5.4 Check and Relief Valve Performance

5.4.1 Check Valve Performance (Log Sheet 6.5)

Setup the unit as shown in Figure 5 and increase the water pressure to 1.0 $\pm$ .1 psig. Water should be visibly observed coming from the LCG Bypass fitting.

5.4.2 Main Reservoir Relief Valve (Log Sheet 6.6)

Setup the unit as shown in Figure 6 and increase the water pressure until water flow is observed and then decrease the pressure until the water flow stops. This test shall be repeated twice. The valve shall crack and reseat at 40-50 psig.

5.4.3 Expansion Tank Relief Valve (Log Sheet 6.6)

Setup the unit as shown in Figure 7 and increase the water pressure until water flow is observed and then decrease the pressure until the water flow stops. The test shall be repeated twice. The valve shall crack and reseat at 40-50 psig.

5.5 Mission Testing Venting (Log Sheet 6.7)

Note: The water used for this test must be saturated with N_2 per Appendix A. Setup the unit as shown in Figure 8 with the dump valve and the feedwater shutoff valve closed and the expansion tank shutoff valve open. Pressurize the O_2 inlet to 4 psig and hold until the water stops flowing from the drain connector. Disconnect the drain connector, shutoff the O_2 supply, and the expansion tank shutoff valve. Open the water fill valve and the dump valve.

5.5 (Continued)

After five minutes, shut the water fill valve and the dump valve. Weigh the unit. The weight increase shall be at least 8.2 pounds. Open the expansion tank shutoff valve and record the water pressure after stabilization. Evacuate the gas loop to a pressure of 3.7-4.0 psia and record the water pressure. The water loop pressure shall agree with the gas loop pressure within .4 psi. Set the feedwater outlet pressure a5 3.0-3.5 psia and open the feedwater shutoff valve. Maintain the gas pressure at 3.7-4.0 psia and hold until the feedwater flow stops. Weigh the feedwater and the unit. The feedwater shall weigh at least 7.8 pounds. Repeat entire test four times for a total of five cycles.

5.6 Mission Test - Non-Venting (Log Sheet 6.8)

Setup the unit as shown in Figure 9 with the expansion tank valve, feedwater shutoff valve, and dump valve closed and the drain connector valve open. Increase the gas pressure to 3.7-4.0 psig and hold until water stops draining from the unit. Close the drain connector valve and weigh the unit. Pressurize the water supply to 5-6 psig and open the supply valve and hold until the weight of the unit stabilizes. The weight increase shall equal at least 1.7 lbs.

5.7 Service (Log Sheet 6.9)

5.7.1 Liquid Loop and Feedwater Circuit Discharge

With the unit upright, open the LCG flow control valves, and the expansion tank, feedwater and umbilical shutoff valves and connect the drain connector. With the dump valve closed, pressurize the O_2 loop to 4-5 psig with dry nitrogen and hold for 10 minutes.

Close the LCG flow control valves and cap the LCG bypass fitting. Connect a 4-5 psig dry nitrogen supply to the water fill connector and water drain connector and purge for one hour. Shutoff the pressure to both the gas loop and feedwater circuit and open the dump valve. With the control panel face

5.7.1 (Continued)

down, connect the 4-5 psig dry nitrogen supply to the LCG inlet and uncap the LCG and LCG bypass fittings and open the LCG flow control valves and purge for one hour. Shutoff the gas supply. Disconnect the gas supply from the LCG inlet and connect it to the LCG outlet fitting. Close the LCG bypass flow control valve. Uncap the umbilical inlet and outlet fittings and increase the gas pressure to 4-5 psig, hold for 30 minutes and then decrease the gas pressure to zero.

5.7.2 Gas Circuit Discharge

Connect a dry nitrogen supply to the O_2 inlet fitting and pressurize to 2-5 psig with the dump valve closed and the O_2 outlet fitting uncapped. Purge the unit for one hour and reduce the pressure to zero.

5.7.3 Final Drying

Remove the caps from all fittings and install the unit in a vacuum chamber. Connect a dry N_2 source to both the LCG inlet and the O_2 inlet. Reduce the chamber pressure to 1 mm Hg and maintain for one hour minimum. Return the chamber to room ambient by supplying dry nitrogen through the O_2 and LCG inlet. Repeat the vacuum/pressurization cycle twice.

5.7.4 Dryout Verification

5.7.4.1 Gas Loop

Close the dump valve and connect a dew pointer to the O_2 outlet. Purge through the O_2 inlet fitting with dry nitrogen at 3-5 psig. Take dew point readings at 5 minute intervals until three successive readings are 0^oF maximum (30 minutes maximum). Shutoff the purge and disconnect the setup.

5.7.4.2 Feedwater Circuit

Open the feedwater and expansion tank shutoff valves and connect a dew pointer to the feedwater outlet. Purge through the water fill connector with dry nitrogen at 3-5 psig. Take dew point readings at 5 minute intervals until three successive readings are $0^{o}F$ maximum (30 minutes maximum). Shut off the purge and disconnect the setup.

5.7.4.3 Liquid Loop

Cap the LCG bypass fitting and the umbilical connectors. Open the umbilical shutoff valve and connect a dew pointer to the LCG outlet. Purge through the LCG inlet connector with dry nitrogen at 3-5 psig. Take dew point readings at 5 minute intervals until three successive readings are $0^{o}F$ maximum (30 minutes maximum). Shut off the purge and disconnect the setup.

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Examination of Product

TEST ENGINEER:

NAME OF RIG: Bench

PROJECT & ENG. ORDER NO.:

SHEET OF | DATE

TEST PLAN NO. TCS-2

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Log Sheet 6.1 Test Number 5.1 Sequence Number

Unit complies with print Yes No

Record Visiual Defects

Weight (Dry) lbs.

C-46

REMARKS:
Ambient temperature
Barometric Pressure

76273

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WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Proof Test
TEST ENGINEER:
NAME OF RIG:
PROJECT & ENG. ORDER NO.:

SHEET OF | DATE
TEST PLAN NO. TCS-2
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Log Sheet 6.2 — Test Number 5.2.1 and 5.2.2 — Sequence Number

	Clock Time	Test Time min.	Test Pressure psig
5.2.1			
5.2.2			

C-47

REMARKS:
Ambient Temperature
Barometric Pressure

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Leakage

TEST ENGINEER

NAME OF RIG

PROJECT & ENG. ORDER NO.

SHEET OF | DATE

TEST PLAN NO. TCS-2

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Log Sheet 6.3 | Test Number 5.3.1 | Sequence Number

Clock Time	Test Time min.	Inlet Press psig	Inlet Flow % scc/min.

C-48

REMARKS:
Ambient Temperature
Barometric Pressure

71066

HSF-178.1A 1/66

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WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Leakage

TEST ENGINEER

NAME OF RIG

PROJECT & ENG. ORDER NO.

SHEET OF

DATE

TEST PLAN NO. TCS-2

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Log Sheet 6.4 Test Number 5.3.2 Sequence Number

Clock Time	Test Time min.	Pig Press psig	Inlet Press psig

Freedom from visual leakage Yes No

REMARKS:
Ambient Temperature
Barometric Pressure

C-49

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WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TITLE OF TEST: Check Valve Performance

TEST ENGINEER

NAME OF RIG

PROJECT & ENG. ORDER NO.

SHEET OF | DATE

TEST PLAN NO. TCS-2

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Log Sheet 6.5 Test Number 5.4.1 Sequence Number

Clock Time	Test Time Min.	Test Press psig

C-50

Pressure at which flow observed psig

REMARKS:
Ambient Temperature
Barometric Pressure

71064

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SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: Relief Valve Performance	SHEET OF	DATE
TEST ENGINEER	TEST PLAN NO. TCS-2	
NAME OF RIG	MODEL NO.	
PROJECT & ENG. ORDER NO.	PART NO.	
	SERIAL NO.	
	OPERATORS	

Log Sheet 6.6 - Test Number 5.4.2 & 5.4.3 Sequence Number

Main Relief Valve

Pressure at which flow starts	psig	psig	psig
Pressure at which flow stops	psig	psig	psig

Expansion Tank Relief Valve

Pressure at which flow starts	psig	psig	psig
Pressure at which flow stops	psig	psig	psig

C-51

REMARKS:
Ambient temperature
Barometric Pressure

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WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

Mission Test Venting
TEST ENGINEER
NAME OF RIG
PROJECT & ENG. ORDER NO.

TEST PLAN NO. TCS-2
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Log Sheet 6.7 Test Number 5.5 Seqeunce Number

Clock Time	Test Time Min.	Unit Weight LBS	O_2 Press psia	H_2O in Press psia	H_2O Out Press psia

C-52

REMARKS:
Ambient Temperature
Barometric Pressure
Water Saturated with N_2 Per Appendix A Yes No

71062

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	SHEET OF	DATE
Mission Test Non Venting	TEST PLAN NO. TCS-2	
TEST ENGINEER	MODEL NO.	
NAME OF RIG	PART NO.	
PROJECT & ENG. ORDER NO.	SERIAL NO.	
	OPERATORS	

Log Sheet 6.8 Test Number 5.6 Sequence Number

Clock Time	Test Time Min.	Unit Weight LBS	O_2 Pressure psig	H_2O Pressure psig

C-53

REMARKS:

Ambient Temperature
Barometric Pressure

HSF-173.1A 1/66

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WINDSOR LOCKS, CONNECTICUT 06096

UA

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Service	SHEET OF	DATE
TEST ENGINEER	TEST PLAN NO. TCS-2	
NAME OF RIG	MODEL NO.	
	PART NO.	
	SERIAL NO.	
PROJECT & ENG. ORDER NO.	OPERATORS	

Log Sheet 6.9 Test Number 5.7 Sequence Number

5.7.1 Liquid Loop and Feedwater Circuit Discharge

	Yes	No
All water discharged from feedwater circuit		
All water discharged from liquid loop		

5.7.2 Gas Circuit

Circuit purged for one hour minimum

5.7.3 Final Drying

Clock Time	Test Time Min.	Chamber Pressure mm Hg

REMARKS:

71688

HSF-175-1A 1/66

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WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST Service

TEST ENGINEER

NAME OF RIG

PROJECT & ENG. ORDER NO.

SHEET OF

DATE

TEST PLAN NO. TCS-2

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Log Sheet 6.9 (Continued)

5.7.4 Dry Out Verification

5.7.4.1 Gas Loop

5.7.4.2 Feedwater Circuit

5.7.4.3 Liquid Loop

Clock Time	Test Time	Press psig	DP °F	Clock Time	Test Time	Press psig	DP °F	Clock Time	Test Time	Press psig	DP °F

REMARKS:

Ambient Temperature
Barometric Pressure

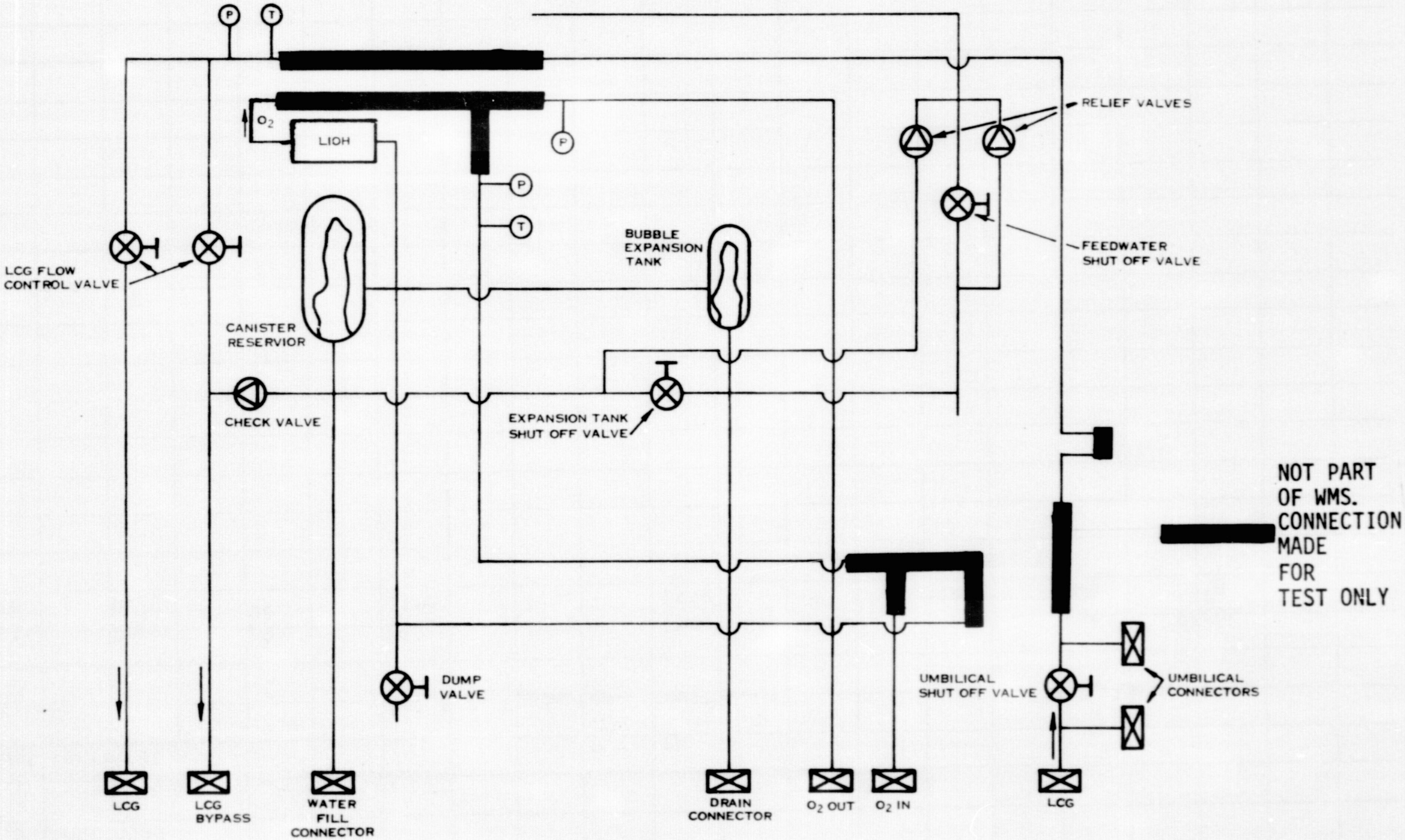


FIGURE 1 - WMS SCHEMATIC

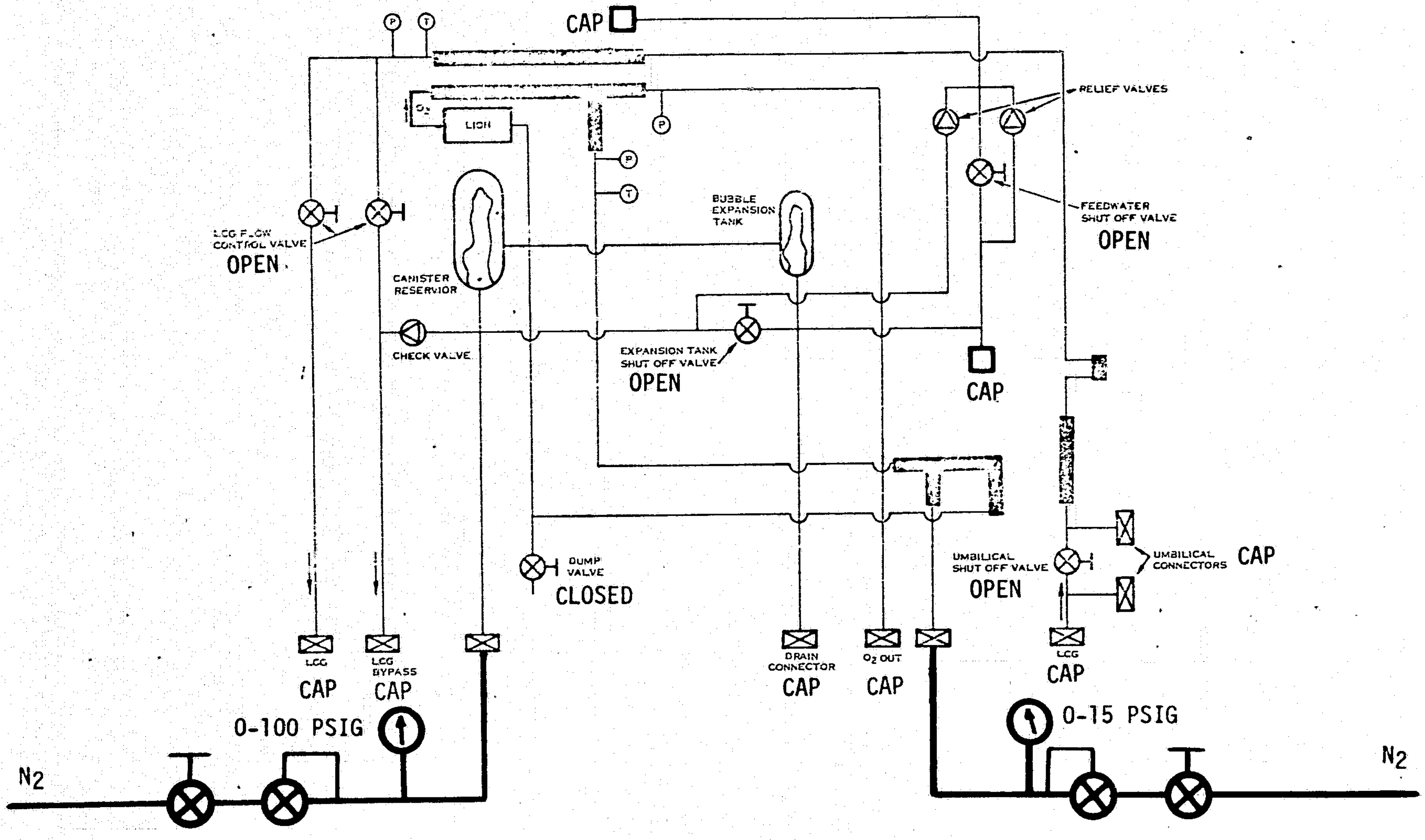


FIGURE 2 - PROOF PRESSURE

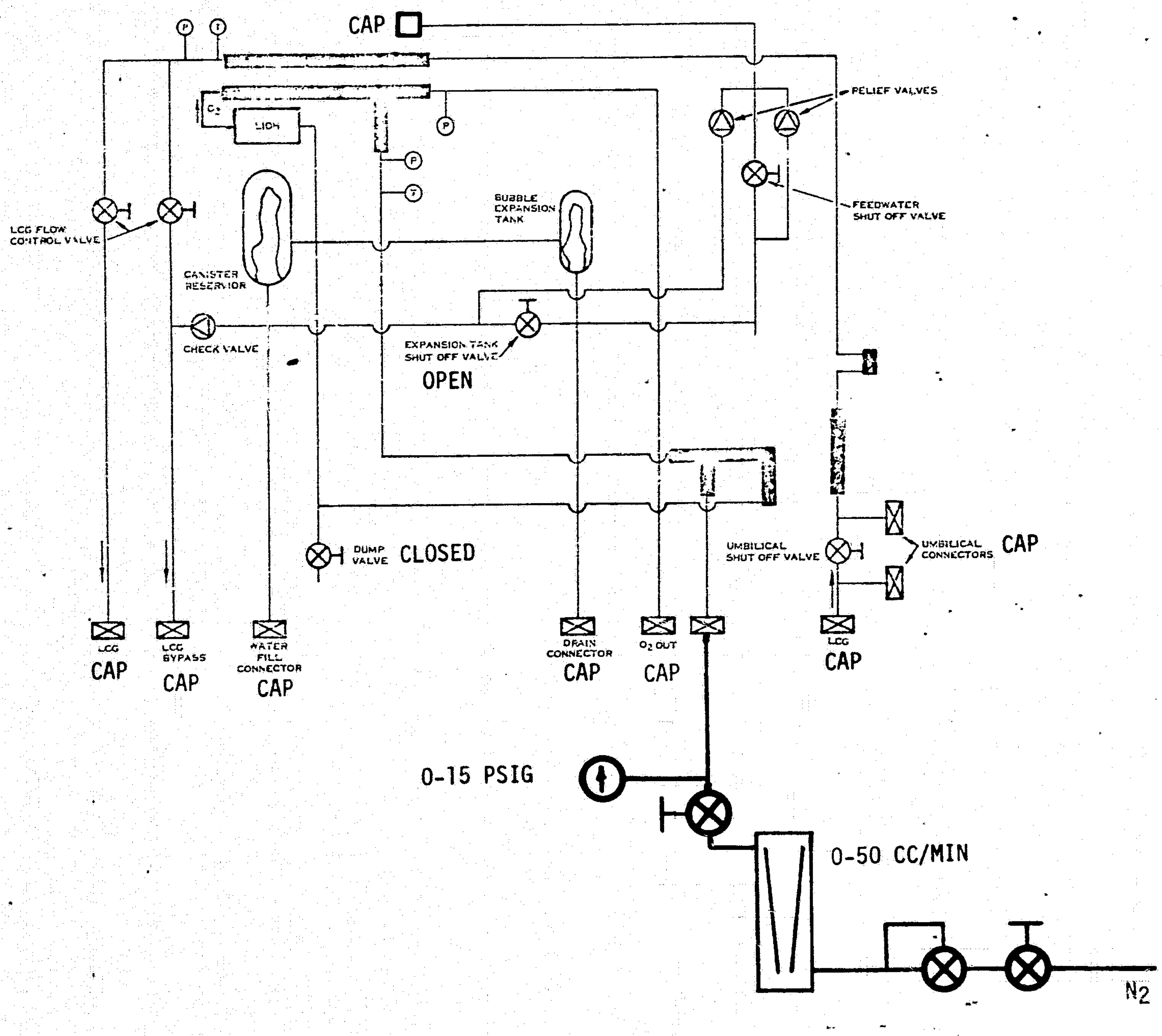


FIGURE 3 - GAS CIRCUIT LEAKAGE

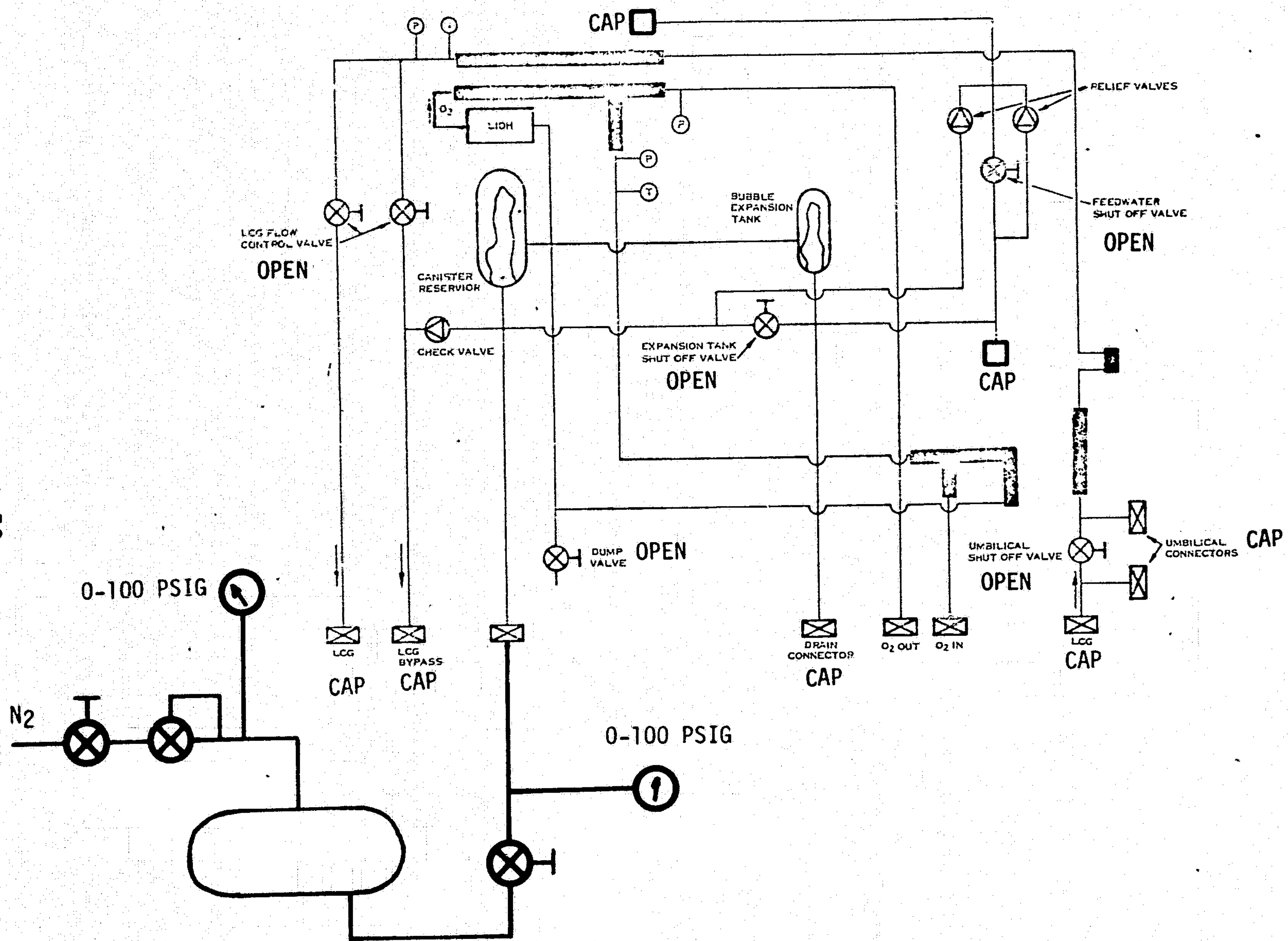


FIGURE 4 - LIQUID CIRCUIT LEAKAGE

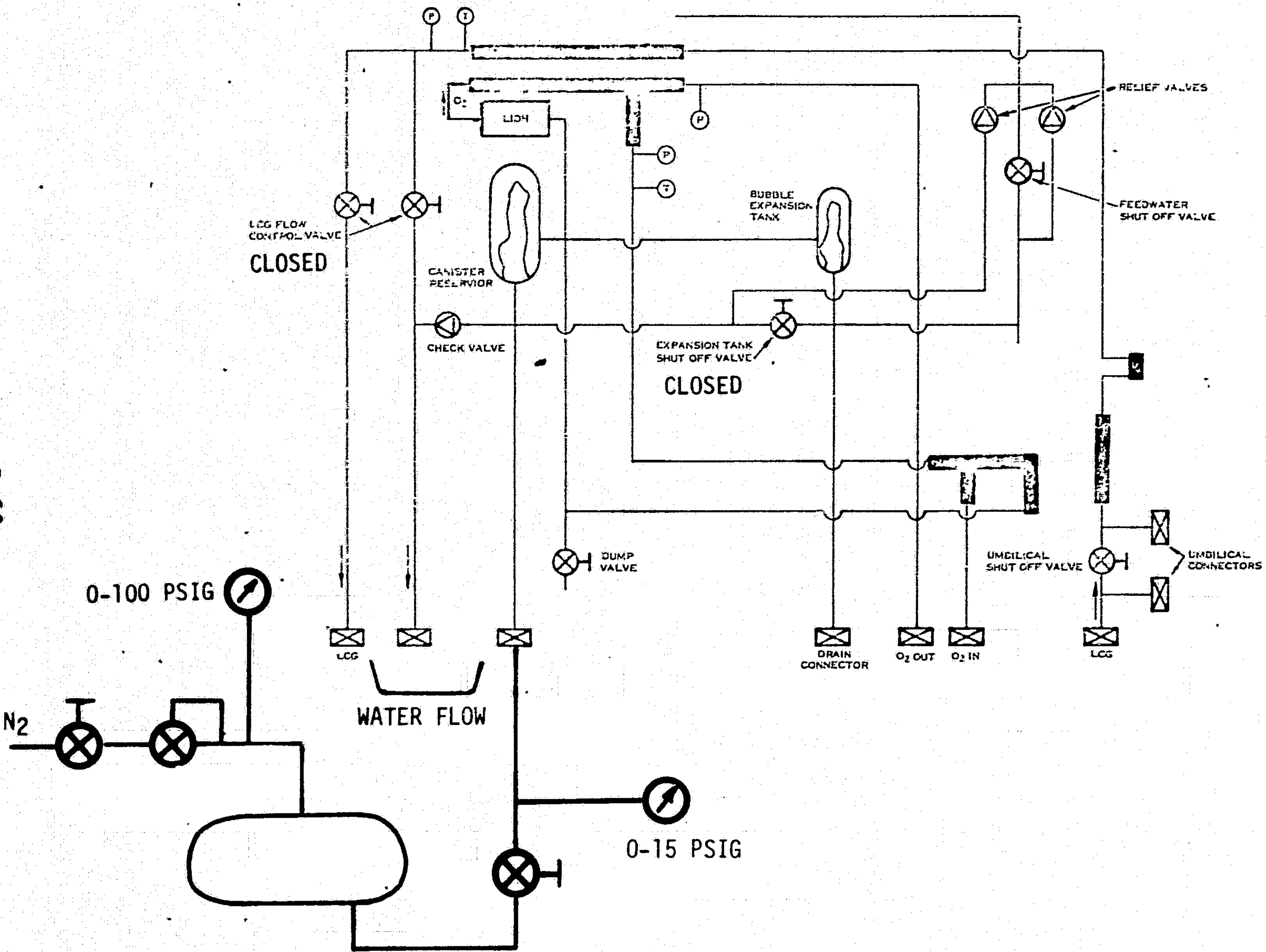


FIGURE 5 - CHECK VALVE PERFORMANCE

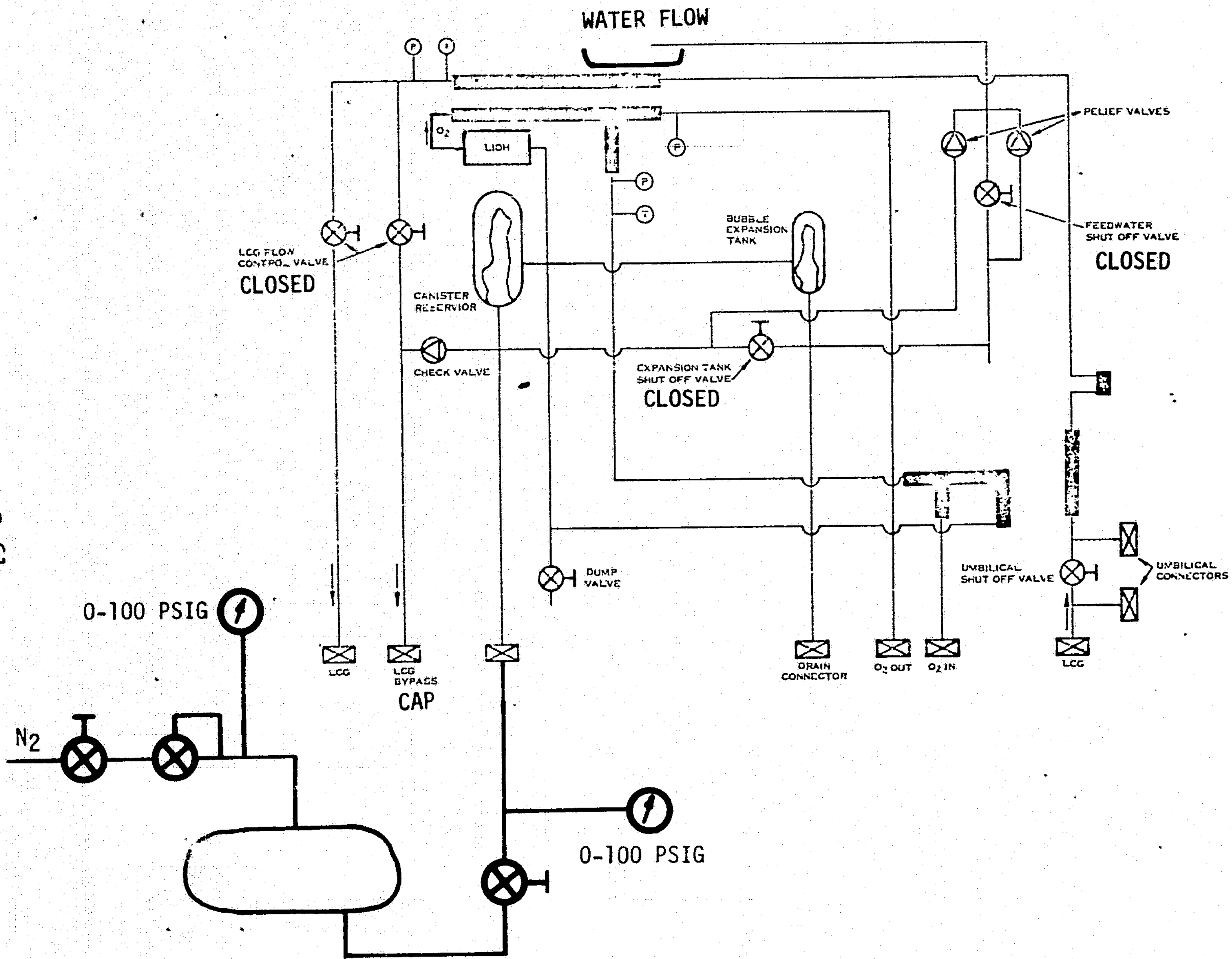


FIGURE 6 - MAIN RELIEF VALVE PERFORMANCE

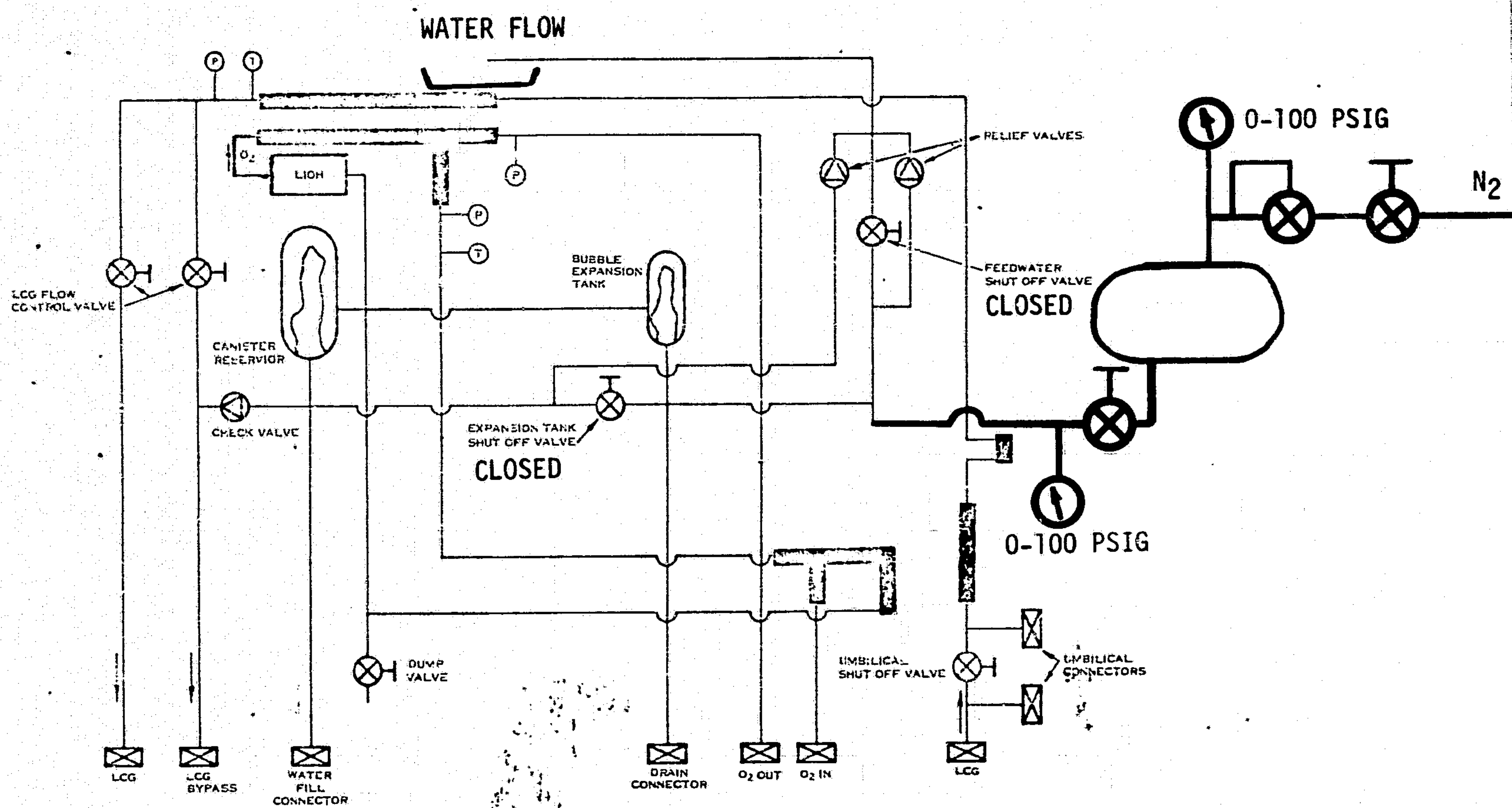


FIGURE 7 - EXPANSION TANK RELIEF VALVE PERFORMANCE

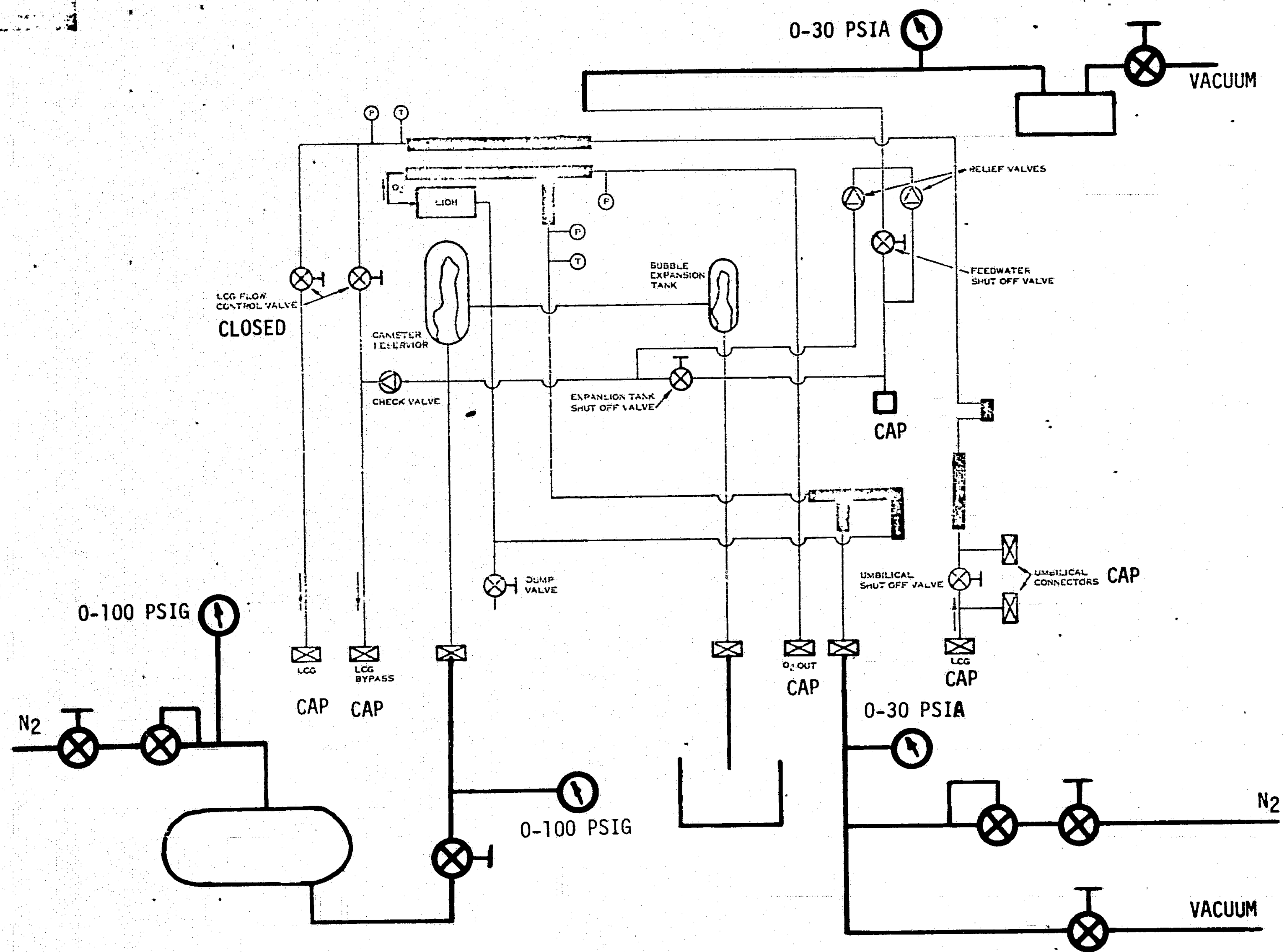


FIGURE 8 - MISSION TEST VENTING

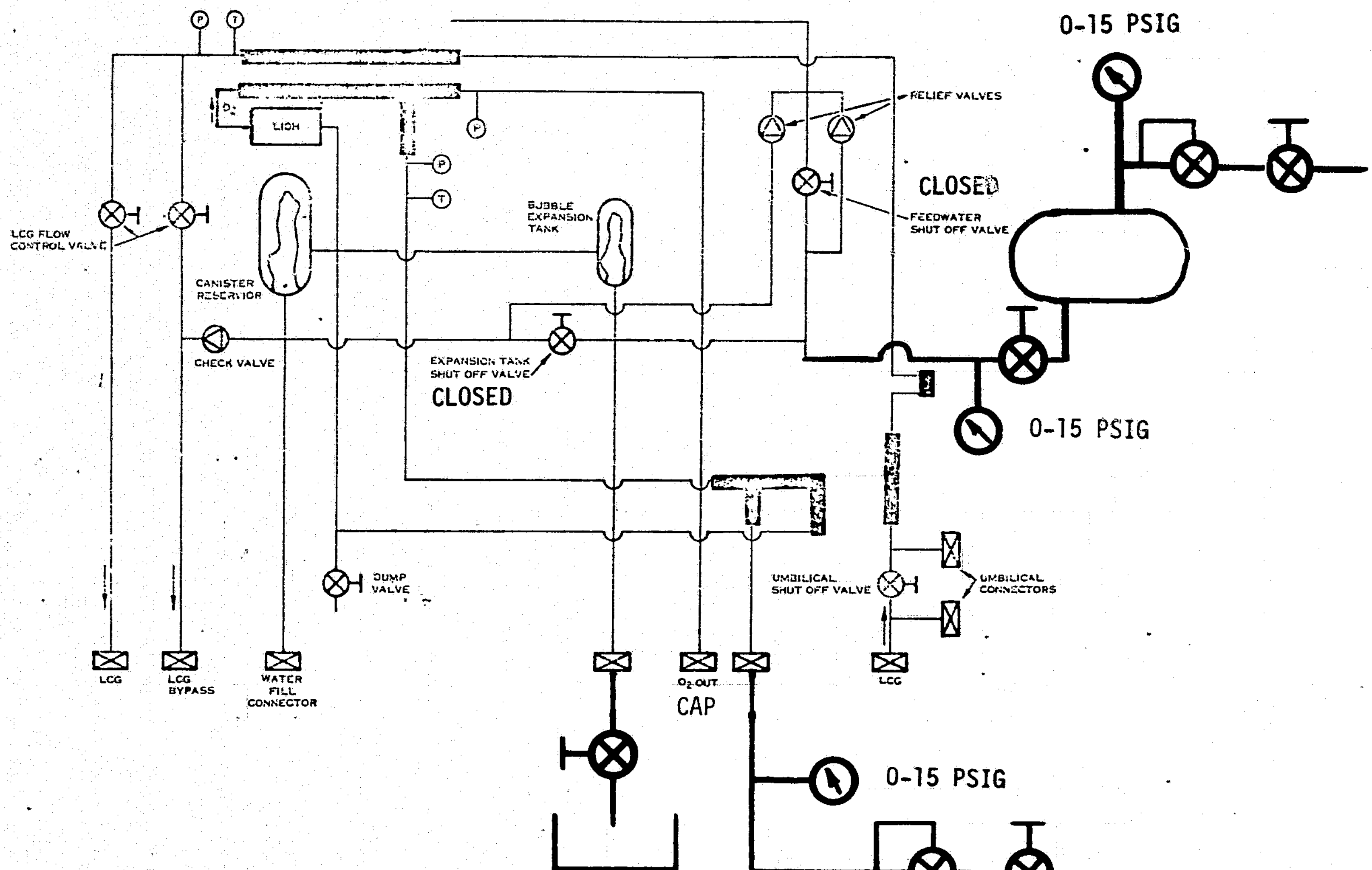


FIGURE 9 - MISSION TEST NON VENTING

SATURATION PROCEDURE

1.0 INTRODUCTION

This document defines the procedure to be used to saturate water with nitrogen for use in TCS testing.

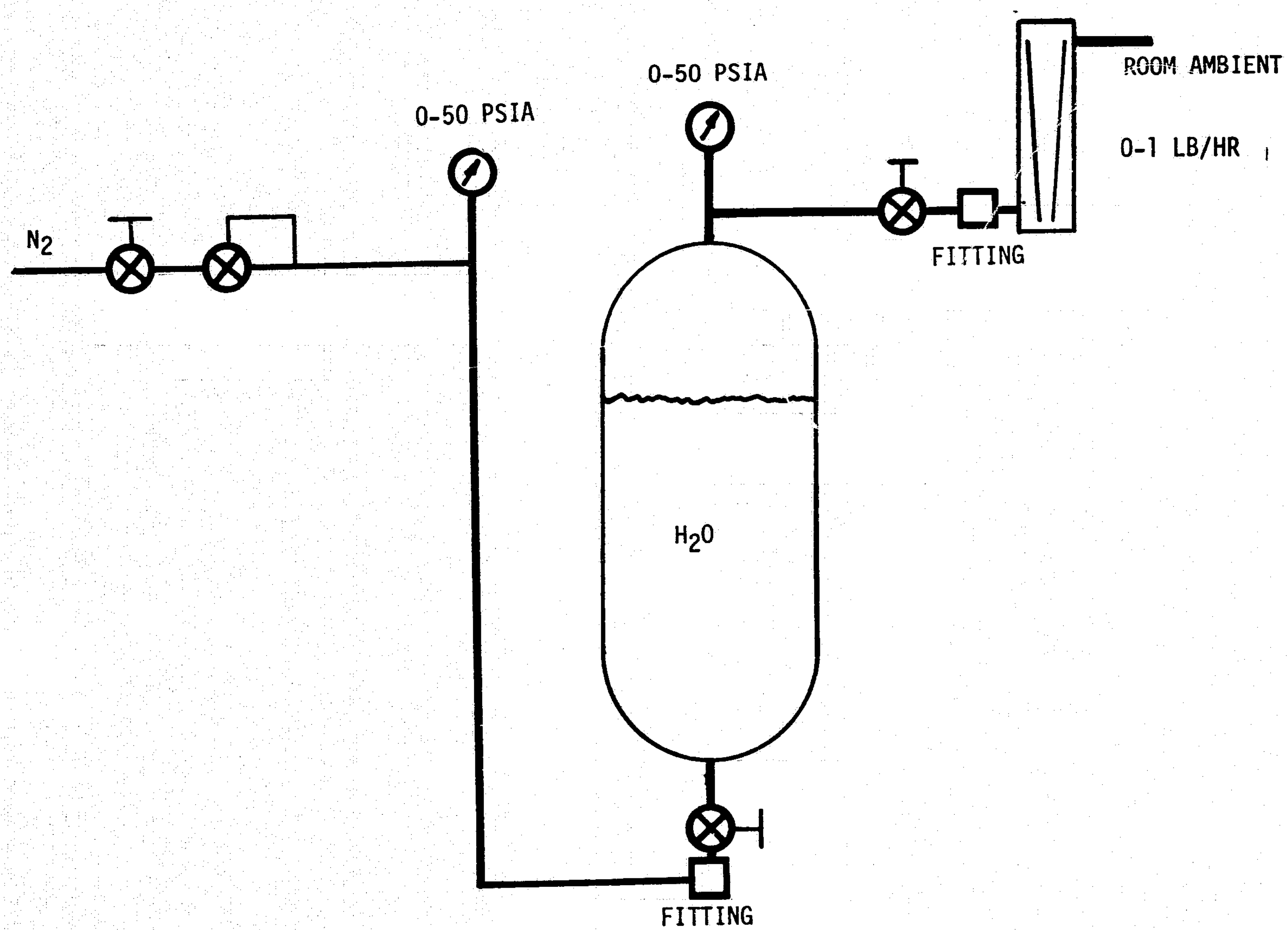
2.0 PROCEDURE

The setup shown in the attached Figure will be used to saturate the water with nitrogen. All lines and fittings must be stainless steel.

The vessel will be charged with at least 50 pounds of water which meets the requirements of SVP 114.

The nitrogen inlet pressure will be set at 35-37 psia, and the flow will be set at .2 lb/hr and will be held for a minimum of 24 hours.

Once the above step has been completed, the pressure in the vessel must be maintained at 35-37 psia. If, at any time, the pressure goes below 33 psia, the preceding step must be repeated.



SETUP FOR SATURATING WATER

EVLSS

THERMAL CONTROL SYSTEM

HUMIDITY CONTROL SUBSYSTEM

DEVELOPMENT TEST PLAN AND PROCEDURE

TCS-3

PREPARED BY: W Bouchelle DATE: 9-19-74

APPROVED BY: F. Goodwin DATE: 9-23-74
ENGINEERING PROGRAM MANAGER

APPROVED BY: R.C. Woodruff DATE: 10-8-74
QUALITY ASSURANCE

APPROVED BY: Michael Rouen DATE: 6-18-75
NASA

1.0 INTRODUCTION

1.1 Purpose

This test plan and procedure defines the Thermal Control System Humidity Control Subsystem (HCS) (second stage) development test program. The HCS first stage (slurper) is tested as part of the HRS test program.

1.2 Scope

This document outlines and describes the item to be tested, test conditions and objectives and performance criteria. The results of this test program will be included in the monthly progress reports.

1.3 Description of Test Item

The test item is the Thermal Control System Humidity Control Subsystem which is defined schematically in Figure 1. The test unit is defined by drawing SVSK 87343.

2.0 APPLICABLE DOCUMENTS

Drawings

SVSK 87343	TCS, Motor/Rotary Fan-Separator

Standards

MIL-O-27210	Oxygen Aviators Breathing, Liquid and Gas
MIL-P-27401	Propellant, Pressurizing Agent, Nitrogen

Specifications

NASA

MSC-SPEC-C21	Water, High Purity (Potable) Specification for

Hamilton Standard

HS 1550	Pre Acceptance, Cleaning, Preservation and Handling of Products
SVP 114	Test Fluid Control (High Purity Water)

3.0 TEST SEQUENCE

Sequence	Test	Test Number
1	Examination of Product	5.1
2	Proof Pressure Test	5.2
3	Leakage Test	5.3
4	Fan Performance Test	5.4
5	Separator Performance Test	5.5
6	Mission Test	5.6
7	OFF Design Test	5.7

4.0 SPECIAL INSTRUCTIONS

4.1 Rigor

The test program shall be conducted under the direction of the cognizant project engineer. Hamilton Standard inspection shall be on a surveillance basis only. Any changes to the approved test plan will be coordinated with NASA.

4.2 Reporting

The results of the test program will be included in the monthly progress reports.

4.3 Control of the Test Item

It shall be the responsibility of the project engineer to insure that the historical log sheets reflect all operations performed on the test article during the test program.

4.4 Equipment Logs (Test Logs)

The test operator shall obtain sufficient data to verify that the test conditions and environmental conditions have been controlled as specified

4.4 (Continued)

herein. This log will be maintained by the test operator(s). In general, the log shall include, but not be limited to, the following data:

a) Test Title and Procedure Section Number

b) Date

c) Environmental Conditions

d) Test Operator

e) Test Equipment

f) Notes and Comments

g) Test Results

Sample Log Sheets are included in Section 6.

4.5 Environmental Requirements

Unless otherwise specified, testing shall be conducted at local Ambient Temperatures and Barometric Pressure. Correction shall be made to provide agreement with the temperature and pressure calibration of the instruments.

4.6 Cleanliness Requirements

Nitrogen conforming to MIL-P-27401 and oxygen conforming to MIL-O-27210 shall be used during testing specified within this document. This gas shall be filtered through a 15 micron absolute filter. The water used during these tests shall be distilled and demineralized per MSC-SPEC-C21 with the following exceptions:

1) Bactericidal agents shall not be used except for those performance tests specified herein.

2) Total solids shall be 3.5 mm/liter maximum.

3) The particulate contamination shall be as follows:

4.6 (Continued)

Particle Size Range (Microns)	Maximum Number of Particles Per 100 ML
0-25	Unlimited
25-50	2,100
50-100	100
100-250	4
250	0

Fibers	Maximum Number of Particles Per 100 ML
100-250	1
250-400	1
400	0

4) The PH range shall be 5.5 to 7.5 at 25°C.

5) The following subparagraphs of MSC-SPEC-C21 are not applicable:

a) 4.1

b) 4.1.3

c) 4.1.6

d) 4.1.7

e) 4.1.8

f) 4.1.10

The external surfaces of the test article shall be maintained to a cleanliness level of HS 1550C1.

NOTE: Water cleaned per SVP 114 meets the requirements above.

5.0 DEVELOPMENT TESTS

5.1 Examination of Product (Log Sheet 6.1)

The item will be examined with respect to surface finish, coating, visual defects and compliance with drawing SVSK 87343. The unit will not be

5.1 (Continued)

disassembled to do a visual examination. Any visual degradation of unit will be recorded during the test program.

5.2 Proof Pressure (Log Sheet 6.2)

5.2.1 Gas and Separator Circuits

Set up the unit as shown in Figure 2 and pressurize the gas circuit with nitrogen to a pressure of 6.0 psig. Maintain this pressure for five minutes. There shall be no permanent visual deformation as a result of this test.

5.2.2 Liquid Circuit

Set up the unit as shown in Figure 3 and pressurize the liquid circuit with nitrogen to a pressure of 54 psig. Maintain this pressure for five minutes. There shall be no permanent visual deformation as a result of this test.

5.3 Leakage Test (Log Sheet 6.3)

5.3.1 Gas and Separator Circuits

Set up the unit as shown in Figure 4 and pressurize the gas circuit with nitrogen to a pressure of 4.0 psig, and the unit will be submerged in water for 15 to 20 minutes. There shall be no evidence of gas leakage.

5.3.2 Liquid Circuit (Log Sheet 6.4)

Set up the unit as shown in Figure 5 and pressurize the liquid circuit with water to a pressure of 36 psig for 15 to 20 minutes. There shall be no evidence of water leakage.

5.4 Fan Performance Test (Log Sheet 6.5)

Set up the unit as shown in Figure 6. Establish a water flow of 20 lb/hr at a pressure of 5 to 20 psig. Maintain the water inlet temperature at 45-55^{o}F.

Set the voltage at 16.8 volts and the fan inlet pressure at 14.7 psia. Close the switch and set the delta P at 2 inch H_2O. Record the flow, inlet and outlet temperature, voltage and current. Increase the delta P in 2 inch H_2O increments to 10 inch H_2O and record the above data at each step. Close the flow valve and record the dead headed pressure rise. Set the delta P at 9 inch H_2O and open the switch. After the unit stops, close the switch and record any start up current and voltage spikes. Repeat the above test at voltages of 18, 20 and 22 volts. Repeat the entire test with an inlet pressure of 18.7 psia. Decrease the inlet pressure to 4 psia and repeat the above test at delta P's of 1, 2, 3, 4 and 5 inch of water. Set the delta P at 4.2 inch of water to check for start up voltage and current spikes.

At 18.7 psia and a delta P inch of water, the flow must be at least 4.4 ACFM. At 4.0 psia and a delta P of 4.2 inch of water, the flow must be at least 6.5 ACFM.

5.5 Separator Performance Test (Log Sheet 6.6)

Set up the unit as shown in Figure 7. Establish a water flow of 20 lb/hr at a pressure of 5 to 20 psig. Maintain the water inlet temperature at 45-55^{o}F.

With the fan running, adjust the voltage and flow to obtain a delta P of 8 inch of water at a flow of 5.5 ACFM. Set the separator gas flow at .1 CFM and set the separator water flow at 3 cc/min. Allow conditions to stabilize and record voltage, current, flows, temperature and pressures.

5.5 (Continued)

The separator outlet flow must equal the inlet flow. Increase the water flow in 3 cc/min increments to 9 cc/min and record the above data at each step. Repeat the above at separator gas flows of .2, .3 and .4 CFM.

Reduce the inlet pressure to 4.0 psia, set the voltage and flow to obtain a delta P of 4.2 inches of water and a flow of 6.5 ACFM and repeat the above performance test.

Increase the inlet pressure to 18.7 psia, set the voltage and flow to obtain a delta P of 9 inches of water and a flow of 4.4 ACFM and repeat the above performance test. Do not change the delta P valve setting after this test. Under all test settings, the separator outlet water must equal the inlet.

5.6 Mission Test (Log Sheet 6.6)

Set up the unit as shown in Figure 7. Establish a water flow of 20 lb/hr at a pressure of 5 to 20 psig. Maintain the water inlet temperature at 45-55°F.

At room pressure, set the voltage at the level required to maintain a flow of 4.4 ACFM and a delta P of 9 inches of water at 18.7 psia (valve obtained from previous test). Record the flow, voltage, delta P and other parameters included on the log sheet.

Set the separator gas flow at .13 CFM and the water flow at 3.5 cc/min. Record all parameters.

Reduce the pressure to 3.7-4.0 psia, maintain the water flow at 3.5 cc/min, set the separator gas flow at .24 ACFM. Record all parameters. Maintain these conditions for 4 hours, recording all data every half

5.6 (Continued)

hour. It is permissible to drain separated water from the burrette during this run.

Return the unit to room pressure and shut the unit down.

The separator outlet water shall equal the inlet.

5.7 <u>OFF Design Test</u> (Log Sheet 6.6)

Set the unit up as shown in Figure 7 and establish the conditions specified in paragraph 5.7 (supply pressure 3.7 to 4.0 psia).

Shut the valve in the separated water outlet and observe the maximum pressure obtained.

Open the outlet valve, set the inlet water at 1.0 cc/min and close the outlet valve. Hold this condition for four hours recording all data every 15 minutes. Shut the test down if the motor current starts to increase above the valve obtained at 18.7 psig in test 5.5. Record the time from start up to shutdown.

Repeat the above test at flows of 2.5 and 4 cc/min.

HSF-175.1A 1/66

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WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	Examination of Product
TEST ENGINEER	
NAME OF RIG	Bench
PROJECT & ENG. ORDER NO.	
SHEET OF	
DATE	
TEST PLAN NO.	TCS-3
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Log Sheet 6.1 Test Number 5.1 Sequence Number ________

Unit Complies with Print

Yes No

Record Visual Defects

C-76

Weight (Dry) ________ Lbs

REMARKS:

Ambient Temperature ________ °F
Barometric Pressure ________ in Hg

71060

HSF-175 1A 1/66

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UA

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	SHEET OF	DATE
Proof Test	TEST PLAN NO. TCS-3	
TEST ENGINEER	MODEL NO.	
NAME OF RIG	PART NO.	
	SERIAL NO.	
PROJECT & ENG. ORDER NO.	OPERATORS	

Log Sheet 6.2 Test Number 5.2.1 and 5.2.2 Sequence Number ______

	Clock Time	Test Time Min	Test Pressure Psig
5.2.1			
5.2.2			

C-77

REMARKS:

Ambient Temperature ______ °F
Barometric Pressure ______ in Hg

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST Leakage	SHEET OF	DATE
TEST ENGINEER	TEST PLAN NO. TCS-3	
NAME OF RIG	MODEL NO.	
PROJECT & ENG. ORDER NO.	PART NO.	
	SERIAL NO.	
	OPERATORS	

Log Sheet 6.3 Test Number 5.3.1 Sequence Number ________

Clock Time	Test Time Min	Inlet Pressure Psig

C-78

Freedom from Leakage

Yes No

REMARKS:

Ambient Temperature ________ °F
Barometric Pressure ________ in Hg

Unit Wiped Free of Bubbles before Test

Yes No

71619

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WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Leakage	SHEET OF	DATE
TEST ENGINEER	TEST PLAN NO. TCS-3	
NAME OF RIG	MODEL NO.	
PROJECT & ENG. ORDER NO.	PART NO.	
	SERIAL NO.	
	OPERATORS	

Log Sheet 6.4 Test Number 5.3.2 Sequence Number

Clock Time	Test Time Min	Pin Press Psig	Inlet Press Psig

Freedom From Visual Leakage

Yes No

C-79

REMARKS:

Ambient Temperature ______ °F
Barometric Pressure ______ in Hg

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WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: Fan Performance
TEST ENGINEER:
NAME OF RIG:
PROJECT & ENG. ORDER NO.:

SHEET OF | DATE
TEST PLAN NO. TCS-3
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Log Sheet 6.5 Test Number 5.4 Sequence Number ________

Clock Time	Test Time		H_2O Flow Lb/Hr	H_2O Pres Psig	~~H_2O Out Temp °F~~	H_2O In Temp °F	Elect ΔT mv/°C	Motor ΔT mv/°F	Gas outlet PSIA	Gas Inlet Psia	Gas Δ P in H_2O	Gas Flow %	Gas Flow CFM	Gas In Temp °F	Gas Out Temp °F	F/R Press PSIA	Voltage VDC		Current Amps		Counter	PPM

C-80

REMARKS:
Ambient Temperature ________ °F
Barometric Pressure ________ in Hg

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WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: Separator Performance	SHEET ___ OF ___ DATE ___
TEST ENGINEER	TEST PLAN NO. TCS-3
NAME OF RIG	MODEL NO.
PROJECT & ENG. ORDER NO.	PART NO.
	SERIAL NO.
	OPERATORS

Log Sheet 6.6 Test Number ________ Sequence Number ________

Clock Time	Test Time		H_2O Flow Lb/Hr	H_2O Pres Psig	H_2O Inlet Temp °F	H_2O Outlet Temp °F		Gas Inlet Press Psia	Gas P In H_2O	Gas Flow %	Gas Flow CFM	Gas Inlet Temp °F	Gas Outlet Temp °F		Sep Gas Flow %	Sep Gas Flow CFM	Sep H_2O In cc/min	Sep H_2O Out cc/min			

REMARKS:

Ambient Temperature ________ °F

Barometric Pressure ________ in Hg

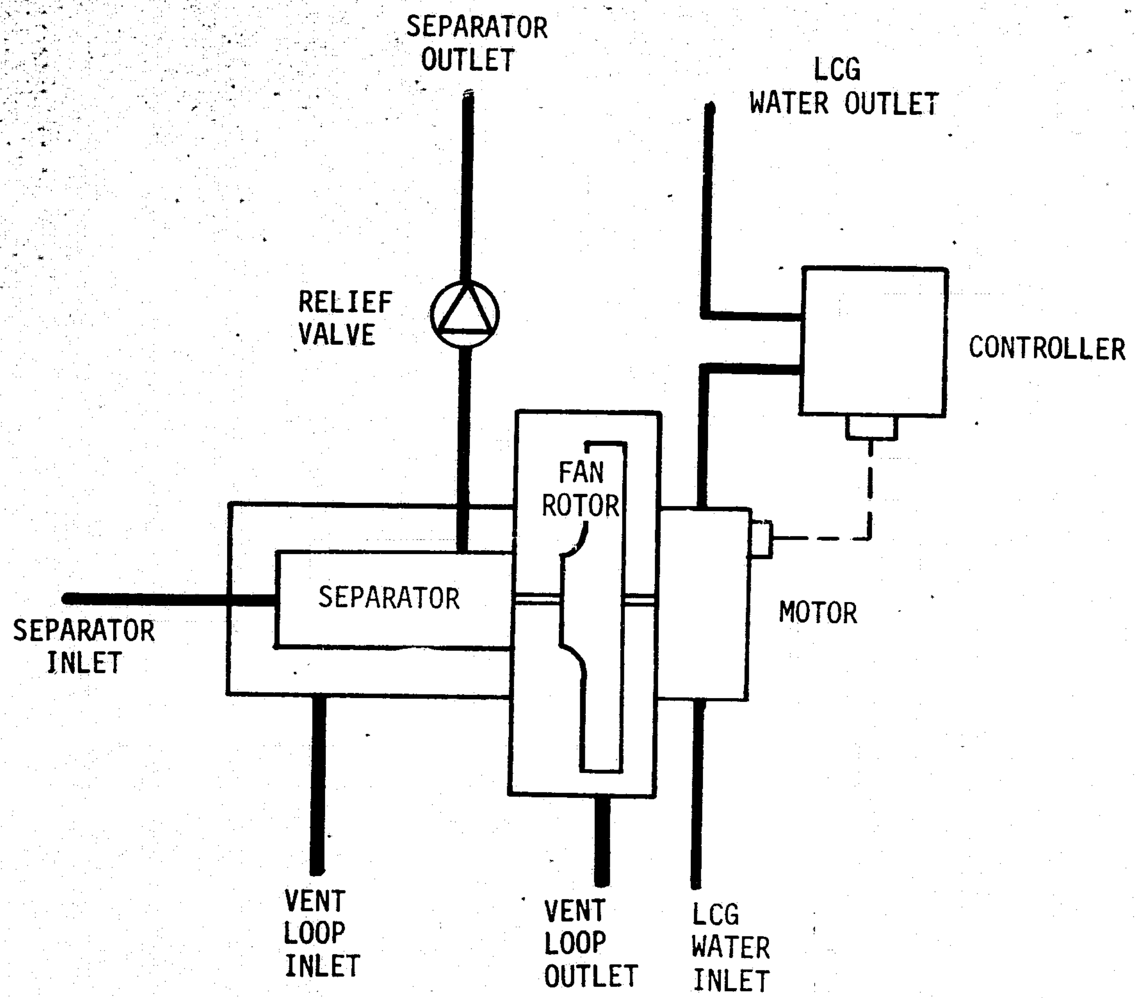

FIGURE 1 - HCS SCHEMATIC (SECOND STAGE)

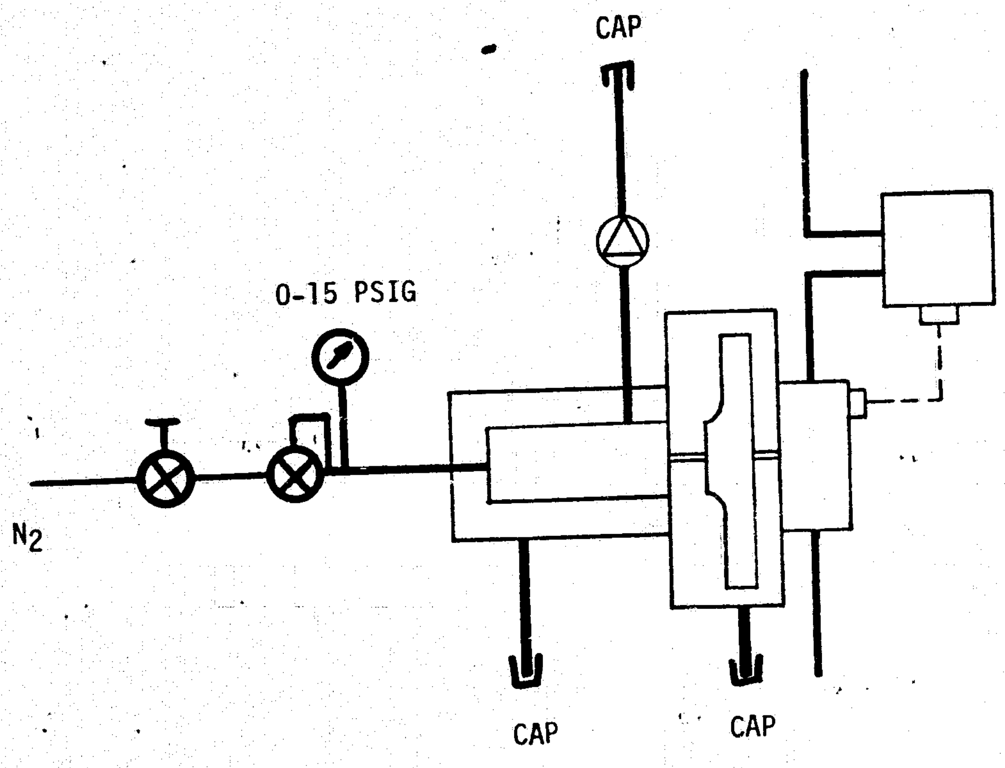

FIGURE 2 - GAS AND SEPARATOR CIRCUITS PROOF TEST

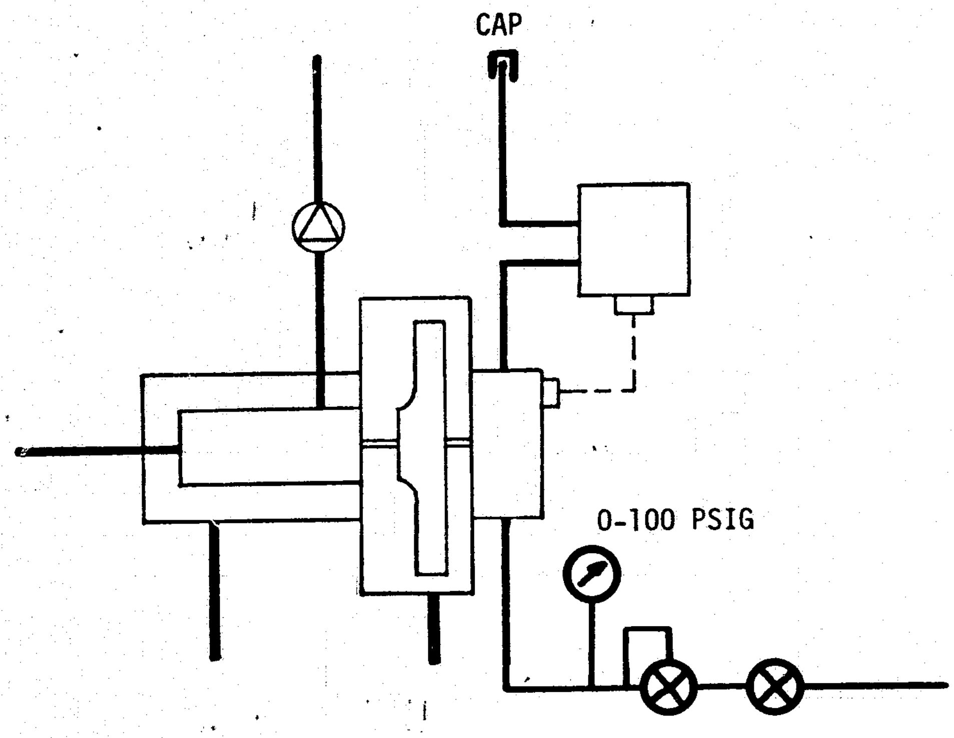

FIGURE 3 - LIQUID CIRCUIT PROOF TEST

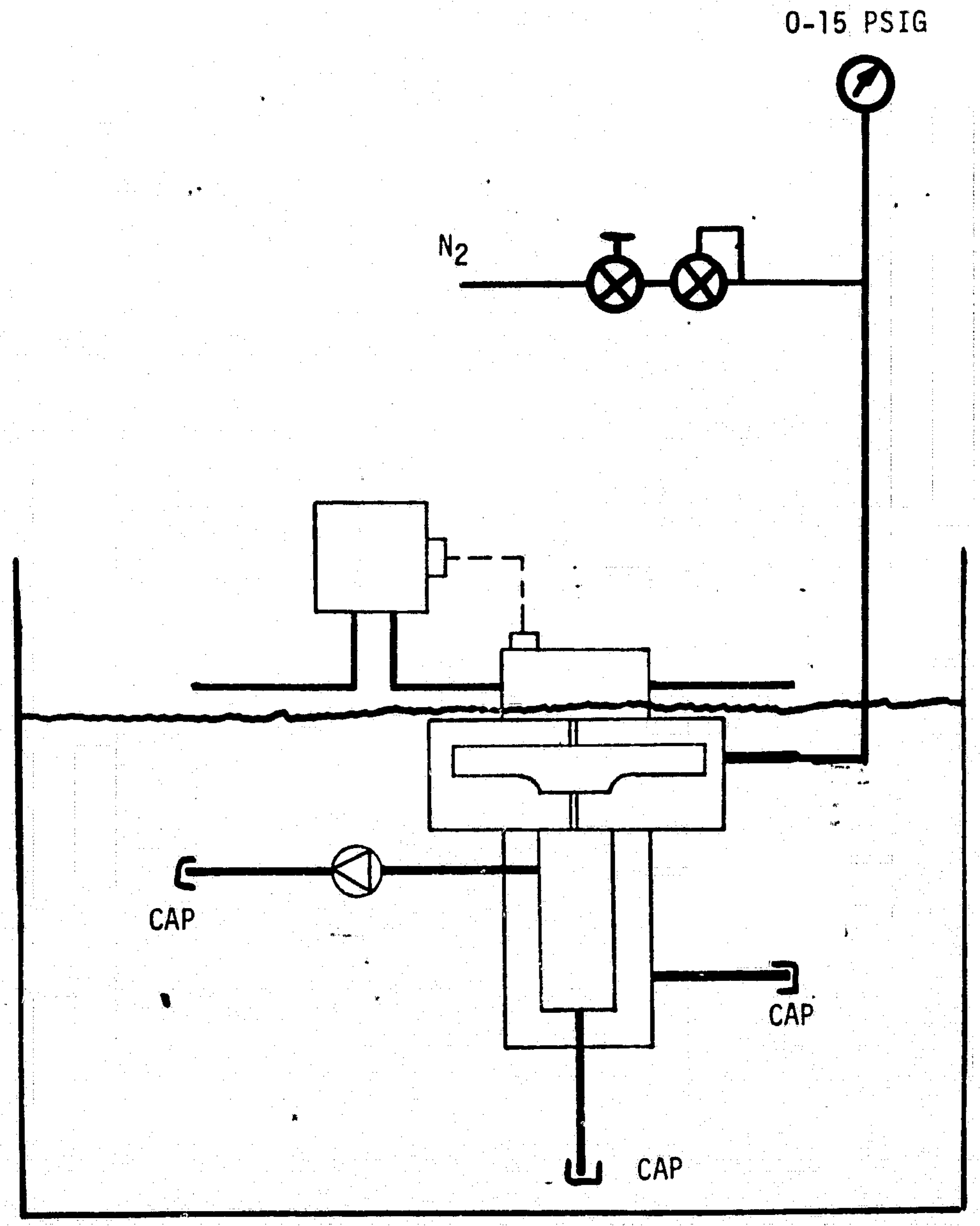

FIGURE 4 - GAS AND SEPARATOR CIRCUIT LEAKAGE TEST

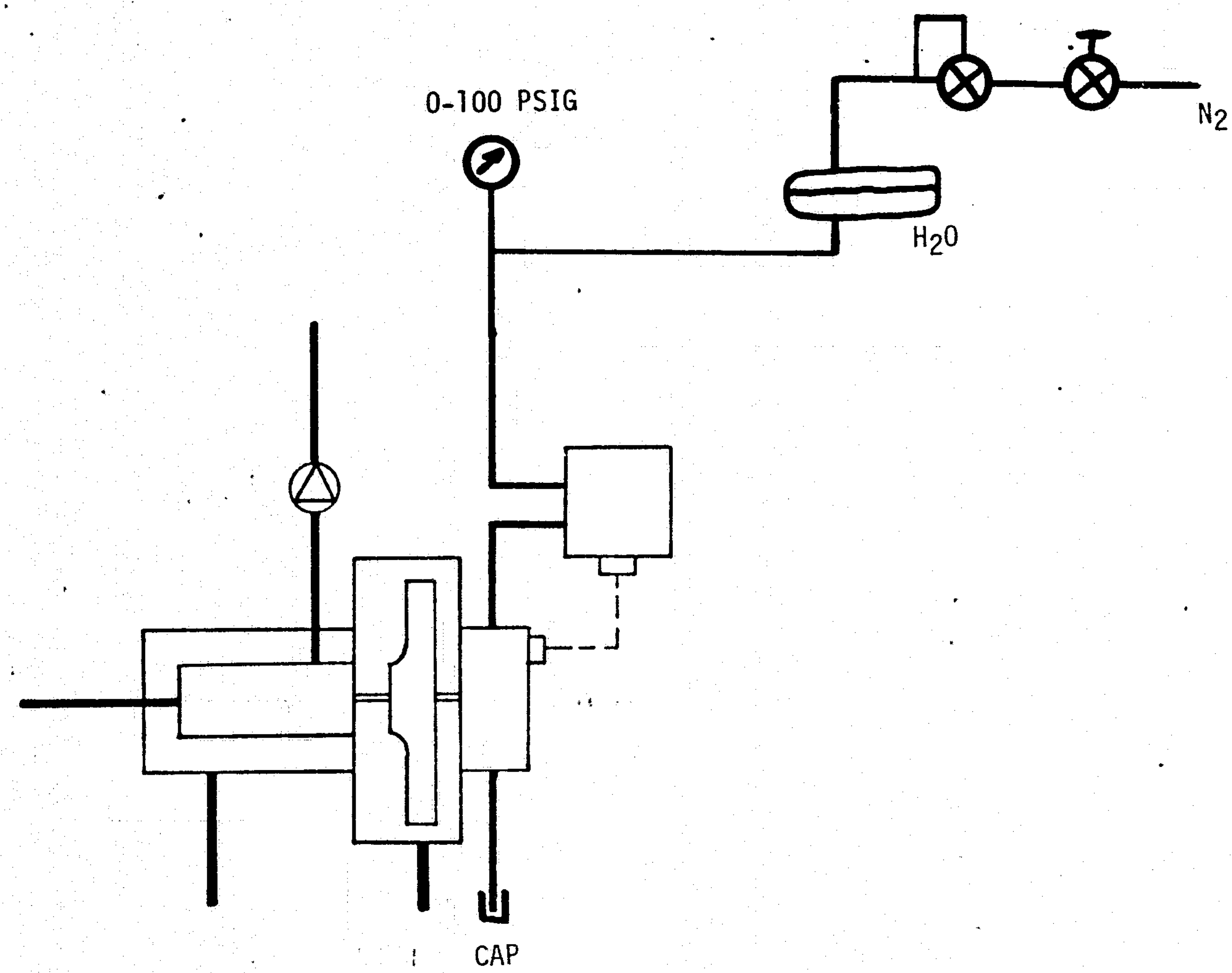

FIGURE 5 - LIQUID CIRCUIT LEAKAGE TEST

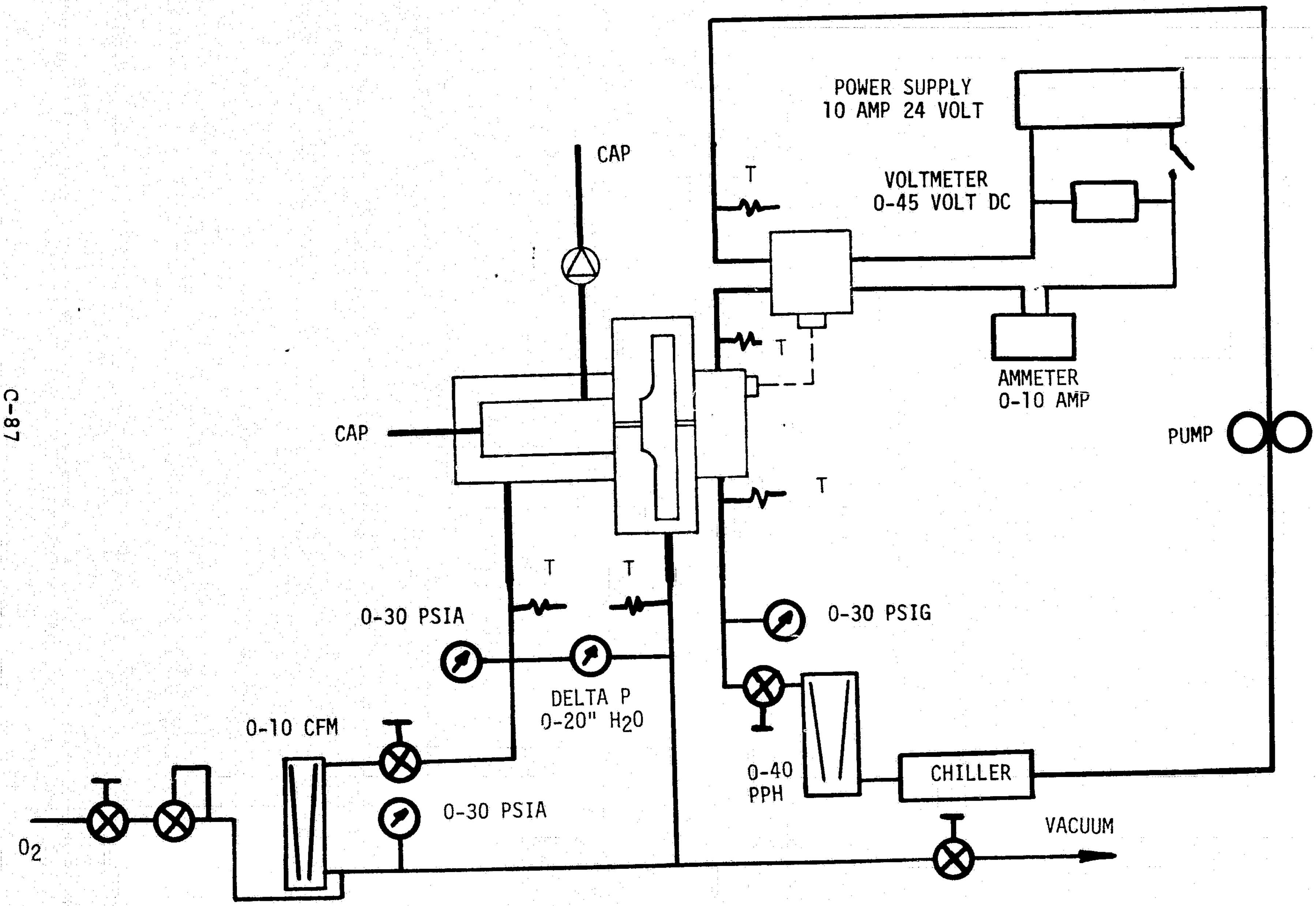

FIGURE 6 - FAN PERFORMANCE TEST

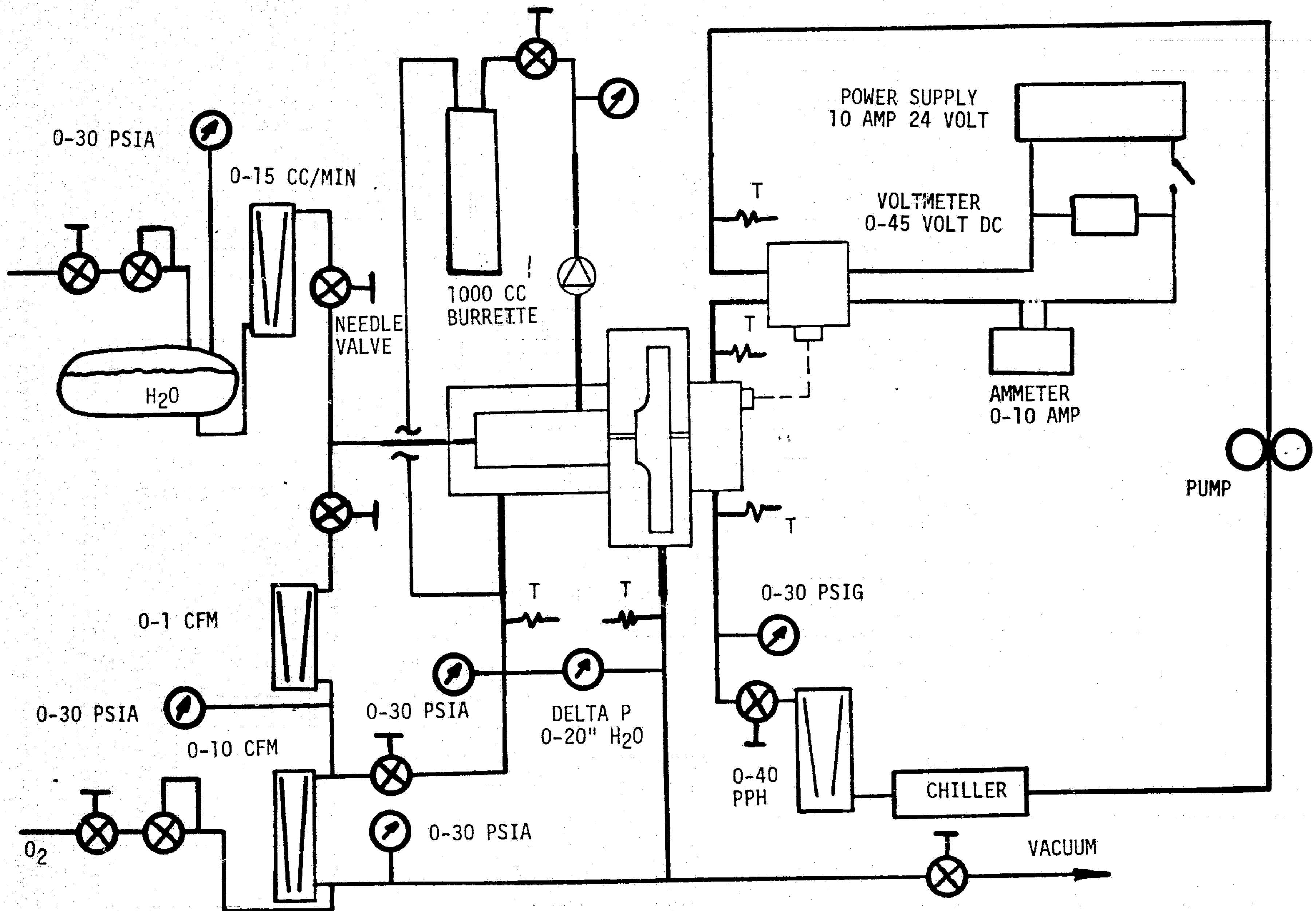

FIGURE 7 - SEPARATOR PERFORMANCE TEST

EVLSS

THERMAL CONTROL SYSTEM

DEVELOPMENT TEST PLAN AND PROCEDURE

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1.0 INTRODUCTION

1.1 Purpose

This test plan and procedure defines the Thermal Control System (TCS) development test program.

1.2 Scope

This document outlines and describes the item to be tested, test conditions and objectives and performance criteria. The results of this test program will be included in the monthly progress reports.

1.3 Description of Test Item

The test item is the Thermal Control System which is defined schematically in Figure 1. The test unit is defined by drawing SVSK 87319.

2.0 APPLICABLE DOCUMENTS

Drawings

SVSK 87319 — Thermal Control System (EVLSS)

Standards

MIL-O-27210 — Oxygen Aviators Breathing, Liquid and Gas

MIL-P-27401 — Propellant, Pressurizing Agent, Nitrogen

Specifications

NASA

MSC-SPEC-C21 — Water, High Purity (Potable) Specification for

Hamilton Standard

HS 1550 — Preacceptance, Cleaning, Preservation and Handling of Products

SVP 114 — Test Fluid Control (High Purity Water)

3.0 TEST SEQUENCE

Sequence	Test	Test Number
1	Examination of Product	5.1
2	Proof Pressure Test	5.2
3	Leakage Test	5.3
4	Mission Test (Hot Start)	5.4.2
5	Mission Test (Cold Start)	5.4.3
6	Mission Test (Room Temp Start)	5.4.4
7	System Pressure Rise vs Flow	5.5
8	Umbilical Operation	5.6
9	Deactivation	5.7

4.0 SPECIAL INSTRUCTIONS

4.1 Rigor

The test program shall be conducted under the direction of the cognizant project engineer. Hamilton Standard inspection shall be on a surveillance basis only. Any changes to the approved test plan will be coordinated with NASA.

4.2 Reporting

The results of the test program will be included in the monthly progress reports.

4.3 Control of the Test Item

It shall be the responsibility of the project engineer to insure that the historical log sheets reflect all operations performed on the test article during the test program.

4.4 Equipment Logs (Test Logs)

The test operator shall obtain sufficient data to verify that the test conditions and environmental conditions have been controlled as specified herein. This log will be maintained by the test operator(s). In general, the log shall include, but not be limited to, the following data:

a. Test Title and Procedure Section Number
b. Date
c. Environmental Conditions
d. Test Operator
e. Test Equipment
f. Notes and Comments
g. Test Results

4.5 Environmental Requirements

Unless otherwise specified, testing shall be conducted at local Ambient Temperatures and Barometric Pressure. Correction shall be made to provide agreement with the temperature and pressure calibration of the instruments.

4.6 Cleanliness Requirements

Nitrogen conforming to MIL-P-27401 and oxygen conforming to MIL-0-27210 shall be used during testing specified within this document. This gas shall be filtered through a 15 micron absolute filter. The water used during these tests shall be distilled and demineralized per MSC-SPEC-C21 with the following exceptions:

1. The water shall contain silver bromide at a concentration of 50-100 ppb.

2. Total solids shall be 3.5 mm/liter maximum.

3. The particulate contamination shall be as follows:

4.6 (Continued)

Particle Size Range (Microns)	Maximum Number of Particles Per 100 ML
0-25	Unlimited
25-50	2,100
50-100	100
100-250	4
250	0

Fibers	Maximum Number of Particles Per 100 ML
100-250	1
250-400	1
400	0

4. The PH range shall be 5.5 to 7.5 at 25°C.
5. The following subparagraphs of MSC-SPEC-C21 are not applicable:
   a. 4.1
   b. 4.1.3
   c. 4.1.6
   d. 4.1.7
   e. 4.1.8
   f. 4.1.10

The external surfaces of the test article shall be maintained to a cleanliness level of HS 1550C1.

NOTE: Water cleaned per SVP 114 meets the requirements above.

5.0 DEVELOPMENT TESTS

5.1 Examination of Product (Log Sheet 6.1)

Examine the item with respect to surface finish, coating, visual defects and compliance with drawing SVSK 87319. Do not disassemble the unit to do a visual examination. Record any visual degradation of unit during the test program. Determine and record the dry weights of the unit.

5.2 Proof Pressure (Log Sheet 6.2)

5.2.1 Gas Circuit

Set up the unit as shown in Figure 2 and pressurize the gas circuit with nitrogen to a pressure of 6.0-6.2 psig. Maintain this pressure for five minutes. There shall be no permanent deformation as a result of this test.

5.2.2 Liquid Circuit

Set up the unit as shown in Figure 2 and pressurize the liquid circuit with nitrogen to a pressure of 54-56 psig. Maintain this pressure for five minutes. There shall be no permanent deformation as a result of this test.

5.3 Leakage Test (Log Sheet 6.3)

5.3.1 Gas Circuit

Set up the unit as shown in Figure 3 and pressurize the gas circuit with nitrogen to a pressure of 4.0-4.2 psig. Set the gas inlet flow as required to maintain the pressure at a constant value and maintain this condition for 15 to 20 minutes. The inlet flow shall not exceed 18 scc/min.

5.3.2 Liquid Circuit (Log Sheet 6.4)

Set up the unit as shown in Figure 4 and pressurize the liquid circuit with water to a pressure of 36 psig for 15 to 20 minutes. There shall be no visible evidence of leakage.

5.4 Performance Testing (Log Sheet 6.5)

5.4.1 General

The TCS shall be set up as shown in Figure 5, and the following parameters shall be observed and recorded at the intervals specified for the individual tests.

a. Gas Circuit

P_{out}, P_{in}, Delta P, T_{in}, T_{out}, Delta T, $T_{DP_{in}}$, $T_{DP_{out}}$, Flow

b. Liquid Circuit

P_{in}, Delta P, T_{in}, T_{out}, Delta T, Flow

c. Feed Water Circuit

P_{in}, T_{in}

NOTE: The feed water must be saturated with N_2 per Appendix A.

5.4.2 Mission Testing (Hot Start)

Set up the unit with the dump valve and the feed water shutoff valve closed, and the expansion tank shutoff valve open. Pressurize the O_2 inlet to 4 psig and hold until the water stops flowing from the drain connector. Disconnect the drain connector, shut off the O_2 supply, and the expansion tank shutoff valve. Open the water fill valve and the dump valve. After five minutes, shut the water fill valve and the dump valve. Weigh the unit. The weight increase shall be at least 8.2 pounds. Open the expansion tank shutoff valve and record the water pressure after

5.4.2 (Continued)

stabilization. Evacuate the gas loop to a pressure of 3.7-4.0 psia and record the water pressure.

Set the gas circuit and liquid circuit, system and ambient conditions as specified in Table I. Once conditions have stabilized, open the feed water valve. The liquid loop outlet temperature shall be below 45°F within 10 minutes.

The gas circuit and liquid circuit conditions will be varied in accordance with Figure 6. After two hours of operation, the feed water will be shut off for one half hour and then shall be restarted. After 1.5 hours of additional operation, the unit will be shutdown, and the system returned to ambient conditions. The unit will meet the requirements defined in Table I. The data will be recorded at each change in condition.

5.4.3 Mission Testing (Cold Start)

Connect the drain connector and with the dump valve and the feed water shutoff valve closed and the expansion tank shutoff valve open, pressurize the O_2 inlet to four psig and hold until the water stops flowing from the drain connector. Disconnect the drain connector, shut off the O_2 supply and the expansion tank shutoff valve. Open the water fill valve and the dump valve. After five minutes, shut the water fill valve and the dump valve. Open the expansion tank shutoff valve and record the water pressure after stabilization. Evacuate the gas loop to a pressure of 3.7-4.0 psia and record the water pressure.

Set the gas circuit and liquid circuit, system and ambient conditions as specified in Table II. Once conditions have stabilized, open the feed water valve. The liquid loop outlet temperature shall be below 45°F within 10 minutes.

5.4.3 (Continued)

The gas circuit and liquid circuit conditions will be varied in accordance with Figure 6. After four hours of operation, the unit will be shutdown and the system returned to ambient conditions. The unit will meet the requirements defined in Table II. The data will be recorded at each change in condition.

5.4.4 Mission Testing (Room Temperature Start)

Connect the drain connector and with the dump valve and the feed water shutoff valve closed and the expansion tank shutoff valve open, pressurize the O_2 inlet to 4 psig and hold until the water stops flowing from the drain connector. Disconnect the drain connector, shut off the O_2 supply and the expansion tank shutoff valve. Open the water fill valve and the dump valve. After five minutes, shut the water fill valve and the dump valve. Open the expansion tank shutoff valve and record the water pressure after stabilization. Evacuate the gas loop to a pressure of 3.7-4.0 psia and record the water pressure.

Set the gas circuit and liquid circuit, system and ambient conditions as specified in Table III. Once conditions have stabilized, open the feed water valve. The liquid loop outlet temperature shall be below $45^{\circ}F$ within 10 minutes.

The gas circuit and liquid circuit conditions will be varied in accordance with Figure 6. After four hours of additional operation, the unit will be shutdown and the system returned to ambient conditions. The unit will meet the requirements defined in Table III. The data will be recorded at each change in condition.

5.5 System Pressure Rise vs Flow

Established a system gas inlet pressure of 3.7 psia and turn on the fan at flows of 0, 5, 6 and 7 acfm record the pressure rise across the system. Repeat the above at inlet pressures of 14.7 psia and 18.7 psia. There is no performance criteria for this test.

5.6 Umbilical Operation

Establish a system gas inlet pressure of 4.0 psia, a gas inlet temperature of 110°F and a water inlet temperature of 50°F. Obtain the liquid loop and gas loop outlet temperatures and the gas loop outlet dew point at inlet dew points of 60°F, 70°F, 80°F and 90°F.

Repeat this test at inlet pressures of 14.7 psia and 18.7 psia. There is no performance criteria for this test.

5.7 Deactivation

5.7.1 Liquid Loop and Feed Water Circuit Discharge

With the unit upright, open the LCG flow control valves, and the expansion tank, feed water and umbilical shutoff valves and connect the drain connector. With the dump valve closed, pressure the O_2 loop to 4-5 psig with dry nitrogen and hold for 10 minutes.

Close the LCG flow control valves and cap the LCG bypass fitting. Connect a 4-5 psig dry nitrogen supply to the water fill connector and water drain connector and purge for one hour. Shut off the pressure to both the gas loop and feed water circuit and open the dump valve. With the control panel face down, connect the 4-5 psig dry nitrogen supply to the LCG inlet and uncap the LCG and LCG bypass fittings and open the LCG flow control valves and purge for one hour. Shut off the gas supply. Disconnect the gas supply from the LCG inlet and connect it to the LCG outlet fitting. Close the LCG bypass flow control valve. Uncap the umbilical inlet and outlet fittings and increase the gas pressure to 4-5 psig, hold for 30 minutes and then decrease the gas pressure to zero.

5.7.2 Gas Circuit Discharge

Connect a dry nitrogen supply to the O_2 inlet fitting and pressurize to 2-5 psig with the dump valve closed and the O_2 outlet fitting uncapped. Purge the unit for one hour and reduce the pressure to zero.

5.7.3 Final Drying

Remove the caps from all fittings and install the unit in a vacuum chamber. Connect a dry N_2 source to both the LCG inlet and the O_2 inlet. Reduce the chamber pressure to 1 mm Hg and maintain for one hour minimum. Return the chamber to room ambient by supplying dry nitrogen through the O_2 and LCG inlet. Repeat the vacuum/pressurization cycle twice.

5.7.4 Dryout Verification

5.7.4.1 Gas Loop

Close the dump valve and connect a dew pointer to the O_2 outlet. Purge through the O_2 inlet fitting with dry nitrogen at 3-5 psig. Take dew point readings at five-minute intervals until three successive readings are $0^{\circ}F$ maximum (30 minutes maximum). Shut off the purge and disconnect the setup.

5.7.4.2 Feed Water Circuit

Open the feed water and expansion tank shutoff valves and connect a dew pointer to the sublimator header. Purge through the water fill connector with dry nitrogen at 3-5 psig. Take dew point readings at five-minute intervals until three successive readings are $0^{\circ}F$ maximum (30 minutes maximum). Shut off the purge and disconnect the setup.

5.7.4.3 Liquid Loop

Cap the LCG bypass fitting and the umbilical connectors. Open the umbilical shutoff valve and connect a dew pointer to the LCG outlet. Purge through the LCG inlet connector with dry nitrogen at 3-5 psig. Take dew point readings at five-minute intervals until three successive readings are $0^{\circ}F$ maximum (30 minutes maximum). Shut off the purge and disconnect the setup.

TABLE I
MISSION TEST (HOT START)

INITIAL CONDITIONS

Liquid Loop:	Flow 240 $\pm$ 5 Lb/Hr, T_{in} 100-105^{o}F Min, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	T_{in} 105-115^{o}F, $T_{DP_{in}}$ 84^{o}F Min, Inlet Pressure 3.85 $\pm$ .15 Psia, Fan On
Feed Water Circuit:	T_{in} 100-105^{o}F, Pressure 3.7-4.0 Psia Feed Water Valve Closed
Ambient:	Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 μ Maximum

MISSION SIMULATION

Liquid Loop:	Flow 240 $\pm$ 5 Lb/Hr, Inlet Pressure 3.5-4.0 Psia, ΔT Per Figure 6
Gas Loop:	Inlet Pressure 3.85 $\pm$ .15 Psia, T_{in} and $T_{DP_{in}}$ Per Figure 6, Fan On
Feed Water Circuit:	T_{in} 70 $\pm$ 15^{o}F, Inlet Pressure 3.7-4.0 Psia Feed Water Valve Open
Ambient:	Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 Maximum

SHUTDOWN

Liquid Loop:	Flow 240 $\pm$ 5 Lb/Hr, Inlet Pressure 3.5-4.0 Psia, ΔT Per Figure 6
Gas Loop:	Inlet Pressure 3.85 $\pm$ 1.5 Psia, T_{in} and $T_{DP_{in}}$ Per Figure 6, Fan On
Feed Water Circuit:	T_{in} 70 $\pm$ 15^{o}F Inlet Pressure 3.7-4.0 Psia Feed Water Valve Closed
Ambient:	Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 μ Maximum

REQUIREMENTS

Start Up:	10 Minutes Maximum for Liquid Loop $T_{out} > 45^{o}$F, Gas Loop Flow 6.3 ACFM Minimum
Mission Simulation:	Gas Circuit T and $T_{DP_{out}}$ 32-50^{o}F, Liquid Circuit Tout 33-45^{o}F
Shutdown:	5 Minutes Maximum to Non Venting

TABLE II
MISSION TEST (COLD START)

INITIAL CONDITIONS

Liquid Loop: Flow 240 $\pm$ 5 Lb/Hr, T_{in} 35^{o}F Maximum, Inlet Pressure 3.5-4.0 Psia

Gas Loop: T_{in} 72^{o}F Minimum, TDP_{in} 50^{o}F Maximum, Inlet Pressure 3.85 $\pm$ .15 Psia, Fan On

Feed Water Circuit: T_{in} 70 $\pm$ 15^{o}F, Pressure 3.7-4.0 Psia Feed Water Valve Closed

Ambient: Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 μ Maximum

MISSION SIMULATION

Liquid Loop: Flow 240 $\pm$ 5 Lb/Hr, Inlet Pressure 3.5-4.0 Psia, ΔT Per Figure 6

Gas Loop: Inlet Pressure 3.85 $\pm$ .15 Psia, T_{in} and TDP_{in} Per Figure 6, Fan On

Feed Water Circuit: T_{in} 70 $\pm$ 15^{o}F, Inlet Pressure 3.7-4.0 Psia Feed Water Valve Open

Ambient: Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 Maximum

SHUTDOWN

Liquid Loop: Flow 240 $\pm$ 5 Lb/Hr, Inlet Pressure 3.5-4.0 Psia, ΔT Per Figure 6

Gas Loop: Inlet Pressure 3.85 $\pm$ 1.5 Psia, T_{in} and TDP_{in} Per Figure 6, Fan On

Feed Water Circuit: T_{in} 70 $\pm$ 15^{o}F Inlet Pressure 3.7-4.0 Psia, Feed Water Valve Closed

Ambient: Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 μ Maximum

REQUIREMENTS

Start Up: 10 Minutes Maximum for Liquid Loop T_{out} $>$ 45^{o}F, Gas Loop Flow 6.3 ACFM Minimum

Mission Simulation: Gas Circuit T and TDP_{out} 32-50^{o}F, Liquid Circuit Tout 33-45^{o}F

Shutdown: 5 Minutes Maximum to Non Venting

TABLE III
MISSION TEST (ROOM TEMPERATURE START)

INITIAL CONDITIONS

Liquid Loop:	Flow 240 $\pm$ 5 Lb/Hr, T_{in} 50^{o}F Minimum, Inlet Pressure 3.5-4.0 Psia
Gas Loop:	T_{in} 72^{o}F Minimum, $T_{DP_{in}}$ 50^{o}F Minimum, Inlet Pressure 3.85 $\pm$ .15 Psia, Fan On
Feed Water Circuit:	T_{in} 70 $\pm$ 15^{o}F, Inlet Pressure 3.7-4.0 Psia, Feed Water Valve Closed
Ambient:	Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 μ Maximum

MISSION SIMULATION

Liquid Loop:	Flow 240 $\pm$ 5 Lb/Hr, Inlet Pressure 3.5-4.0 Psia, ΔT Per Figure 6
Gas Loop:	Inlet Pressure 3.85 $\pm$ .15 Psia, T_{in} and $T_{DP_{in}}$ Per Figure 6, Fan On
Feed Water Circuit:	T_{in} 70 $\pm$ 15^{o}F, Inlet Pressure 3.7-4.0 Psia, Feed Water Valve Open
Ambient:	Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 Maximum

SHUTDOWN

Liquid Loop:	Flow 240 $\pm$ 5 Lb/Hr, Inlet Pressure 3.5-4.0 Psia, ΔT Per Figure 6
Gas Loop:	Inlet Pressure 3.85 $\pm$ 1.5 Psia, T_{in} and $T_{DP_{in}}$ Per Figure 6, Fan On
Feed Water Circuit:	T_{in} 70 $\pm$ 15^{o}F Inlet Pressure 3.7-4.0 Psia Feed Water Valve Closed
Ambient:	Temperature 70 $\pm$ 15^{o}F, Pressure 1,000 μ Maximum

REQUIREMENTS

Start Up:	10 Minutes Maximum for Liquid Loop $T_{out} > 45^{o}$F, Gas Loop Flow 6.3 ACFM Minimum
Mission Simulation:	Gas Circuit T and $T_{DP_{out}}$ 32-50^{o}F, Liquid Circuit T_{out} 33-45^{o}F
Shutdown:	5 Minutes Maximum to Non Venting

HSF-175.1A 1/66

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WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	Examination of Product
TEST ENGINEER	
NAME OF RIG	Bench
PROJECT & ENG. ORDER NO.	
SHEET OF	DATE
TEST PLAN NO.	TCS-4
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Log Sheet 6.1 Test Number 5.1 Sequence Number

Unit complies with print Yes No

Record Visual Defects

C-103

Weight (Dry) lbs.

REMARKS:
Ambient temperature
Barometric Pressure

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UA

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Proof Test

TEST ENGINEER

NAME OF RIG

PROJECT & ENG. ORDER NO.

SHEET OF DATE

TEST PLAN NO. TCS-4

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Log Sheet 6.2 Test Number 5.2.1 and 5.2.2 Sequence Number

	Clock Time	Test Time min.	Test Pressure psig
5.2.1			
5.2.2			

C-104

REMARKS:

Ambient Temperature
Barometric Pressure

71068

HSF-175.1A 1/66

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LOG OF TEST

TYPE OF TEST: Leakage
TEST ENGINEER:
NAME OF RIG:
PROJECT & ENG. ORDER NO.:

SHEET   OF   DATE
TEST PLAN NO. TCS-4
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Log Sheet 6.3   Test Number 5.3.1   Sequence Number

Clock Time	Test Time min.	Inlet Press psig	Inlet Flow % scc/min.

C-105

REMARKS:
Ambient Temperature
Barometric Pressure

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Leakage
TEST ENGINEER:
NAME OF RIG:
PROJECT & ENG. ORDER NO.:

SHEET OF | DATE
TEST PLAN NO. TCS-4
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Log Sheet 6.4 Test Number 5.3.2 Sequence Number

Clock Time	Test Time min.	Pig Press psig	Inlet Press psig

C-106

Freedom from visual leakage Yes No

REMARKS:
Ambient Temperature
Barometric Pressure

71065

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SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST	
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	
SHEET OF	DATE
TEST PLAN NO.	TCS-4
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Log Sheet 6.5 Test Number Sequence Number

Clock	Test	Gas Circuit										Liquid Circuit								Rig Leakage		
Time	Time	P_{in}	P_{out}	ΔP	T_{in}	T_{out}	ΔT	DP_{in}	DP_{out}	Flow		P_{in}	ΔP	T_{in}	T_{out}	ΔT	Flow			Flow		P
	Min	Psia	Psia	Psi	°F	°F	°F	°F	°F	%	CFM	Psia	Psi	°F	°F	°F	%	#/Hr		%	#/Hr	Psi

C-107

REMARKS:

71056

HSF-178.1A 1/66

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LOG OF TEST

TYPE OF TEST	SHEET OF	DATE
TEST ENGINEER	TEST PLAN NO. TCS-4	
NAME OF RIG	MODEL NO.	
	PART NO.	
	SERIAL NO.	
PROJECT & ENG. ORDER NO.	OPERATORS	

Log Sheet 6.5 (Continued)

Feedwater Circuit Pin Psia	Tin °F	Rig Pressure μ	Header Pressure μ

C-108

REMARKS:

Ambient Temperature °F
Barometric Pressure in Hg

71625

HSF 175.1A 1/66

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LOG OF TEST

TYPE OF TEST	Deactivation
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	
SHEET OF	DATE
TEST PLAN NO.	TCS-4
MODEL NO.	
PART NO	
SERIAL NO.	
OPERATORS	

Log Sheet 6.6   Test Number 5.5   Sequence Number

5.5.1 Liquid Loop and Feedwater Circuit Discharge

	Yes	No
All water discharged from feedwater circuit		
All water discharged from liquid loop		

5.5.2 Gas Circuit

Circuit purged for one hour minimum

5.5.3 Final Drying

Clock Time	Test Time Min.	Chamber Pressure mm Hg

C-109

REMARKS:

HSF-175.1A 1/66

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LOG OF TEST

TYPE OF TEST: Deactivation	SHEET OF	DATE
TEST ENGINEER	TEST PLAN NO. TCS-4	
NAME OF RIG	MODEL NO.	
PROJECT & ENG. ORDER NO.	PART NO.	
	SERIAL NO.	
	OPERATORS	

Log Sheet 6.6 (Continued)

5.5.4 Dry Out Verification

5.5.4.1 Gas Loop				5.7.5.2 Feedwater Circuit				5.7.5.3 Liquid Loop			
Clock Time	Test Time	Press psig	DP °F	Clock Time	Test Time	Press psig	DP °F	Clock Time	Test Time	Press psig	DP °F

C-110

REMARKS:
Ambient Temperature
Barometric Pressure

71617

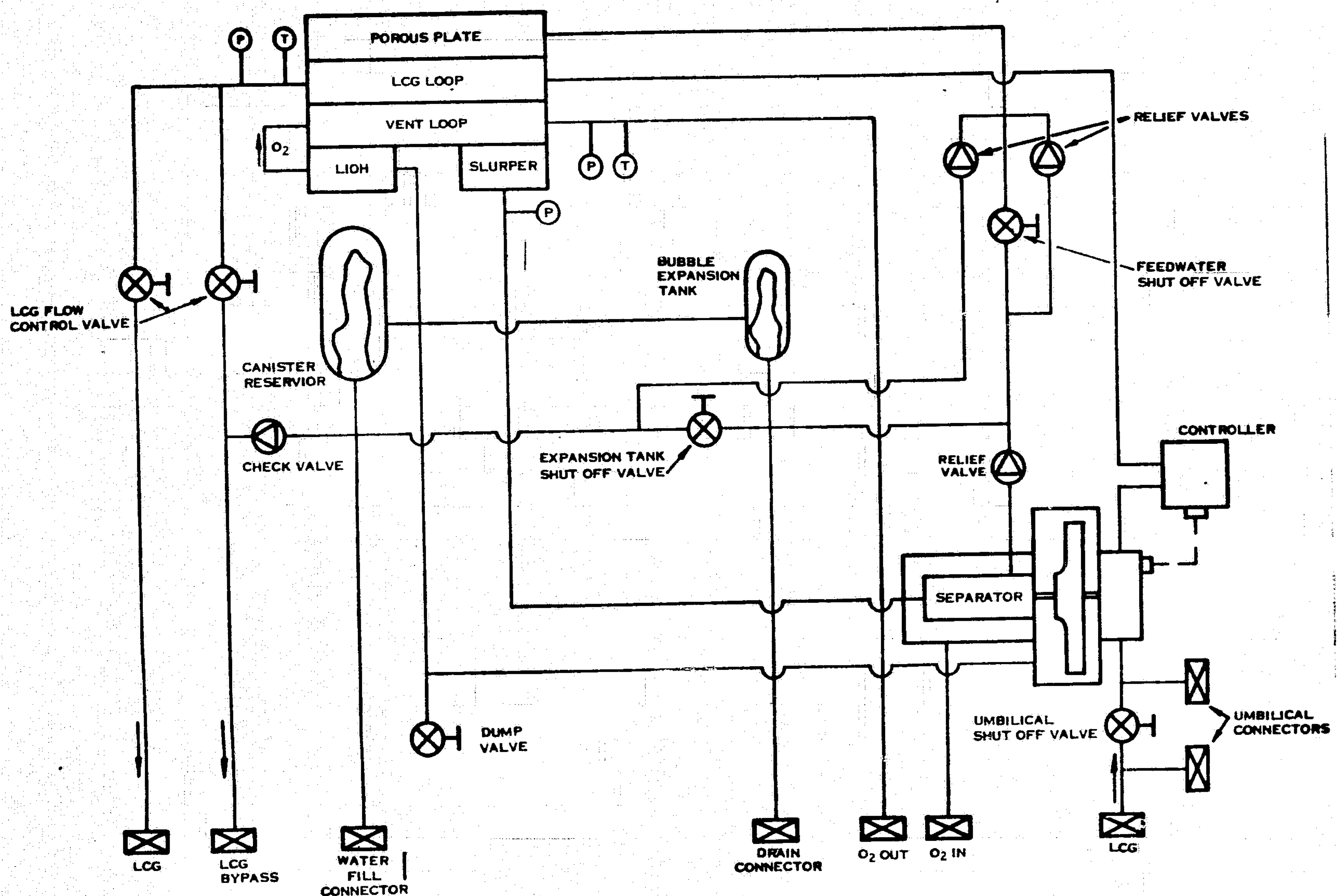


FIGURE 1 **TCS SCHEMATIC**

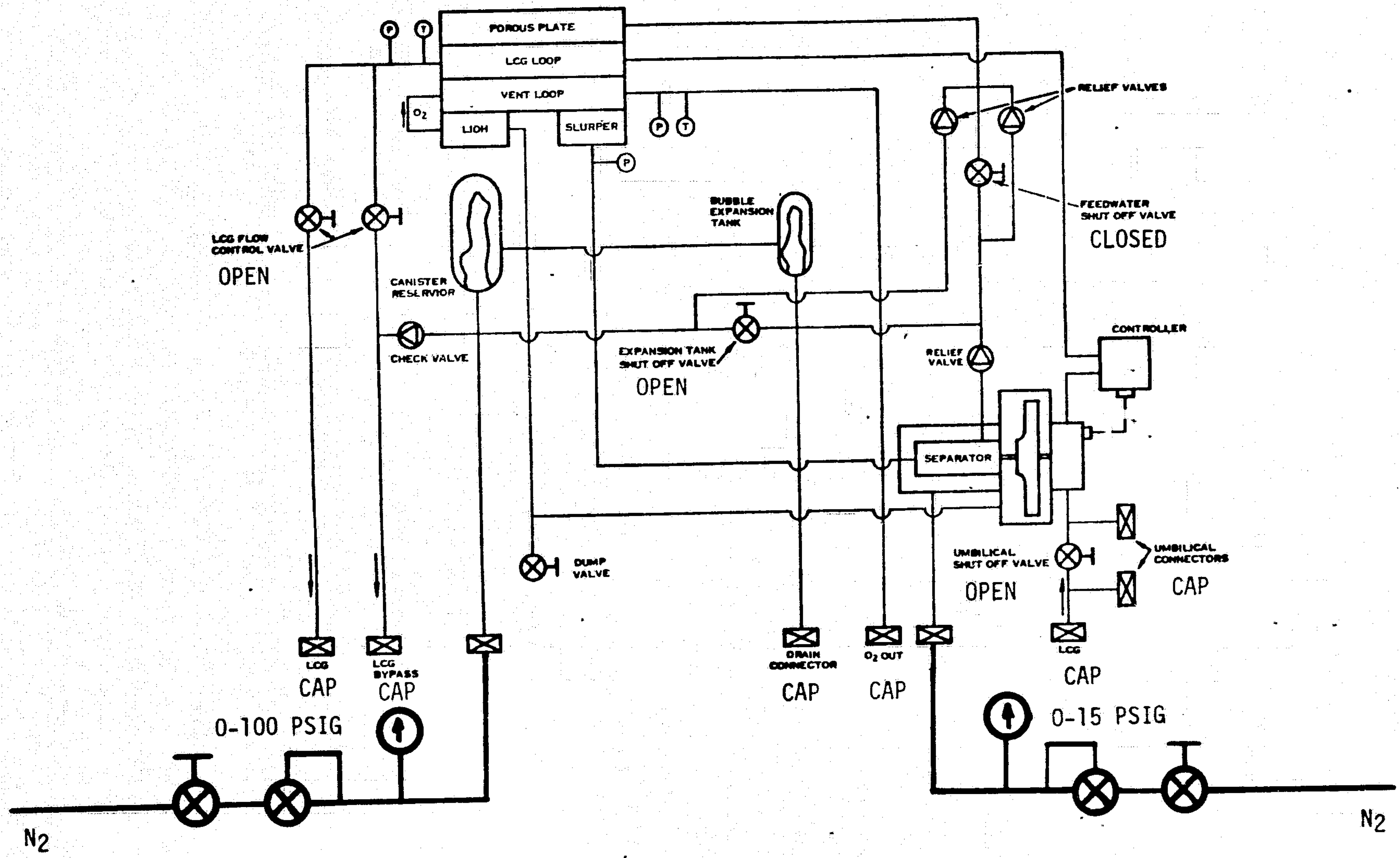


FIGURE 2 - PROOF PRESSURE

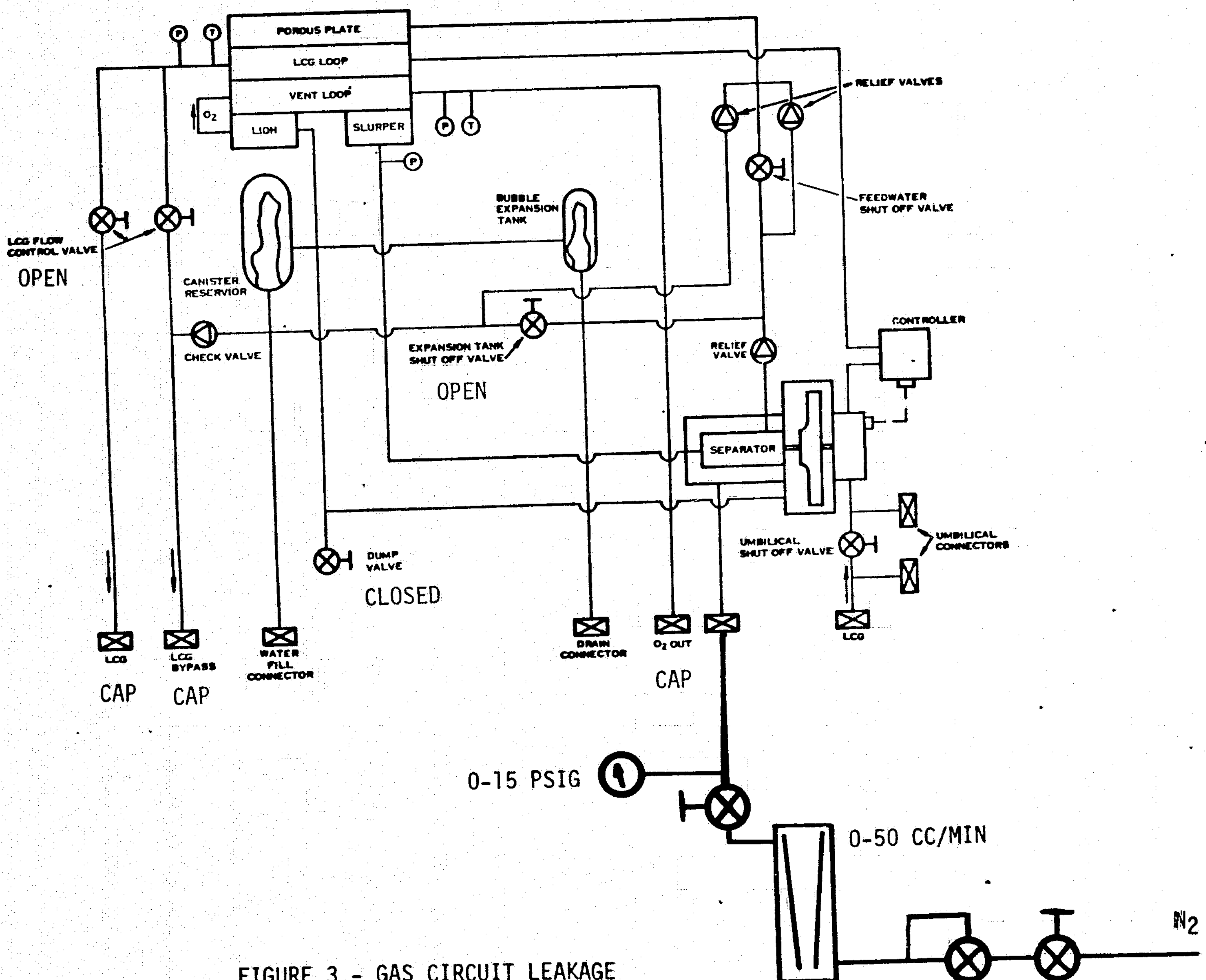


FIGURE 3 - GAS CIRCUIT LEAKAGE

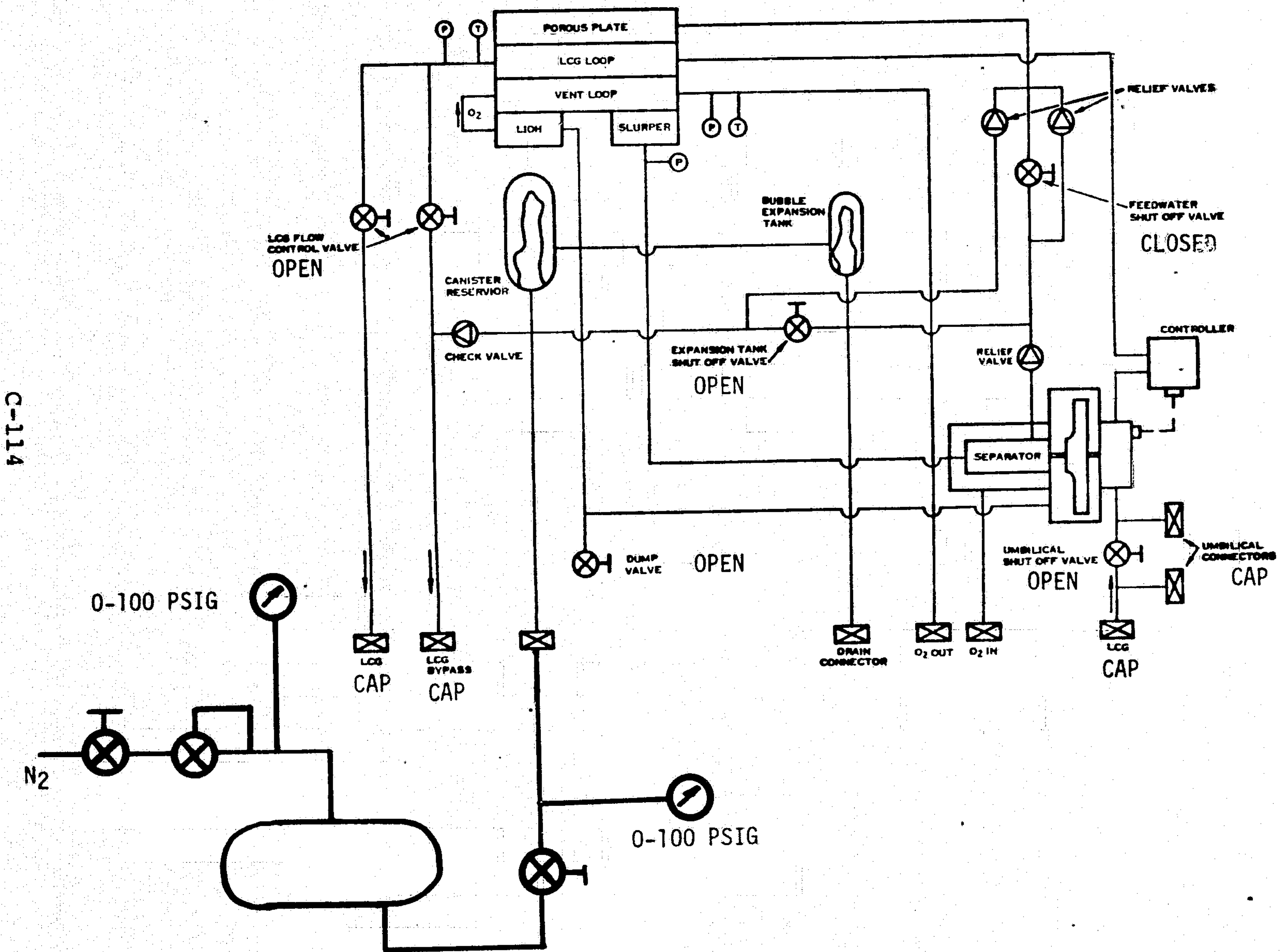


FIGURE 4 - LIQUID CIRCUIT LEAKAGE

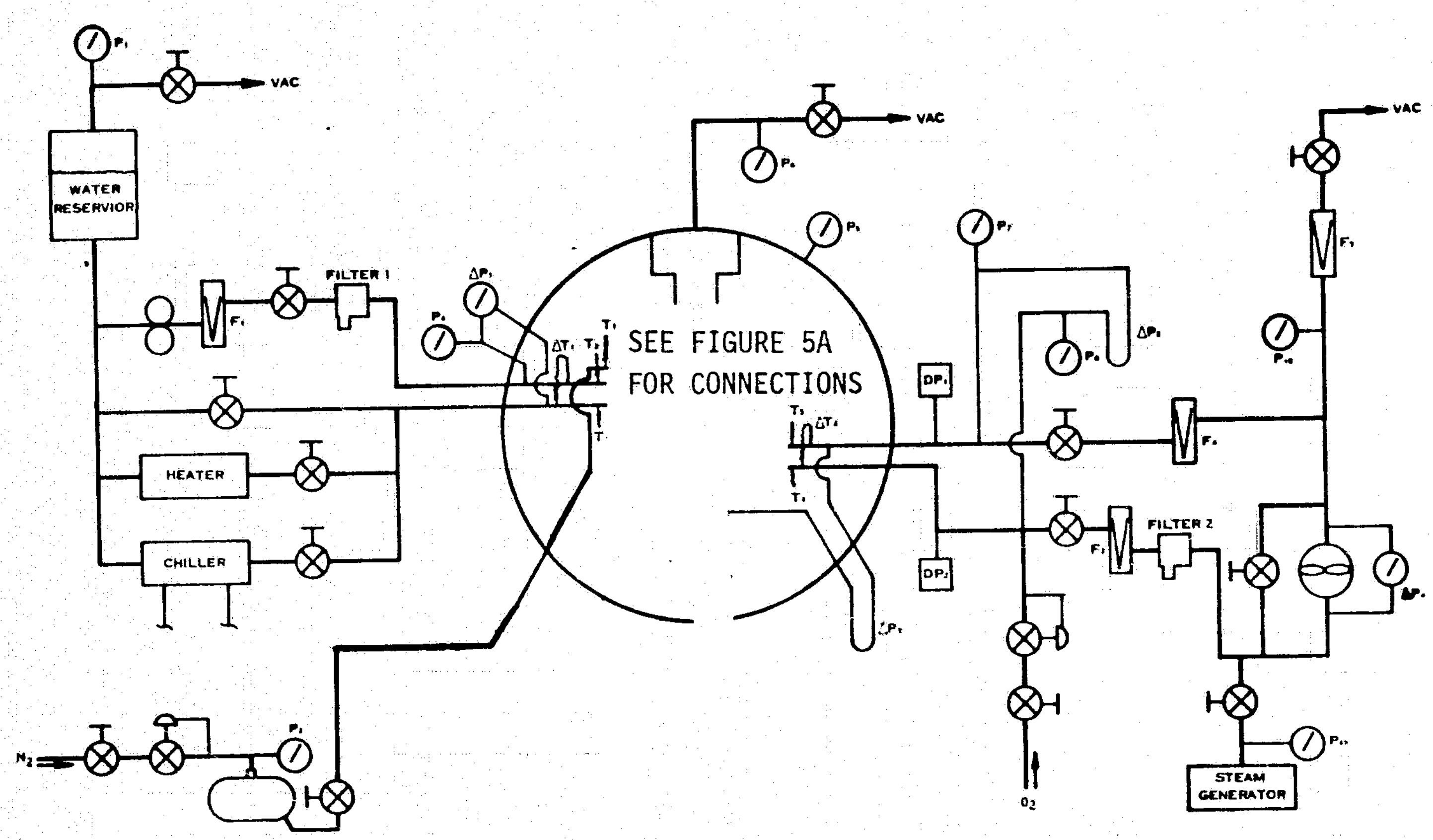


FIGURE 5 - PERFORMANCE TEST SETUP

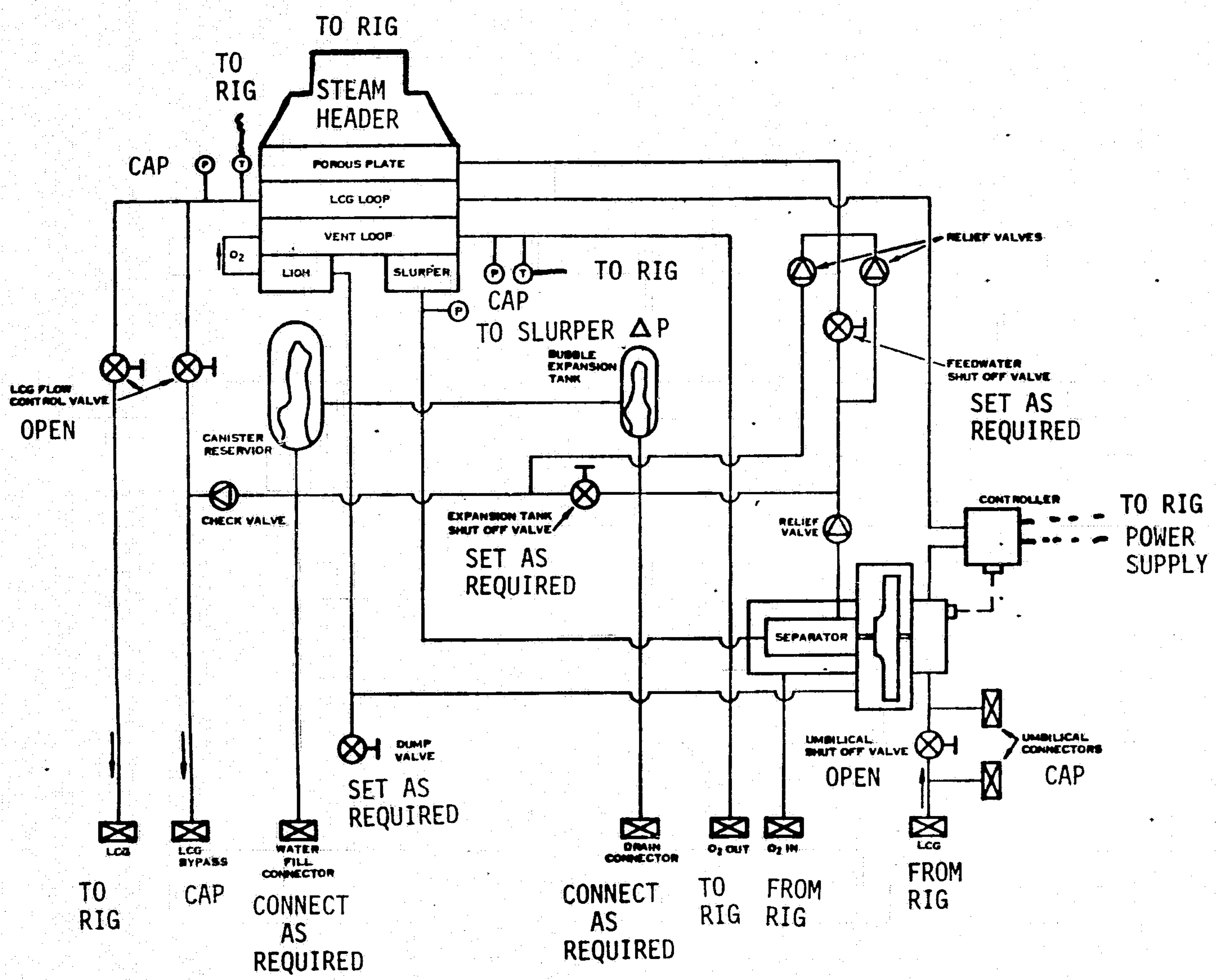
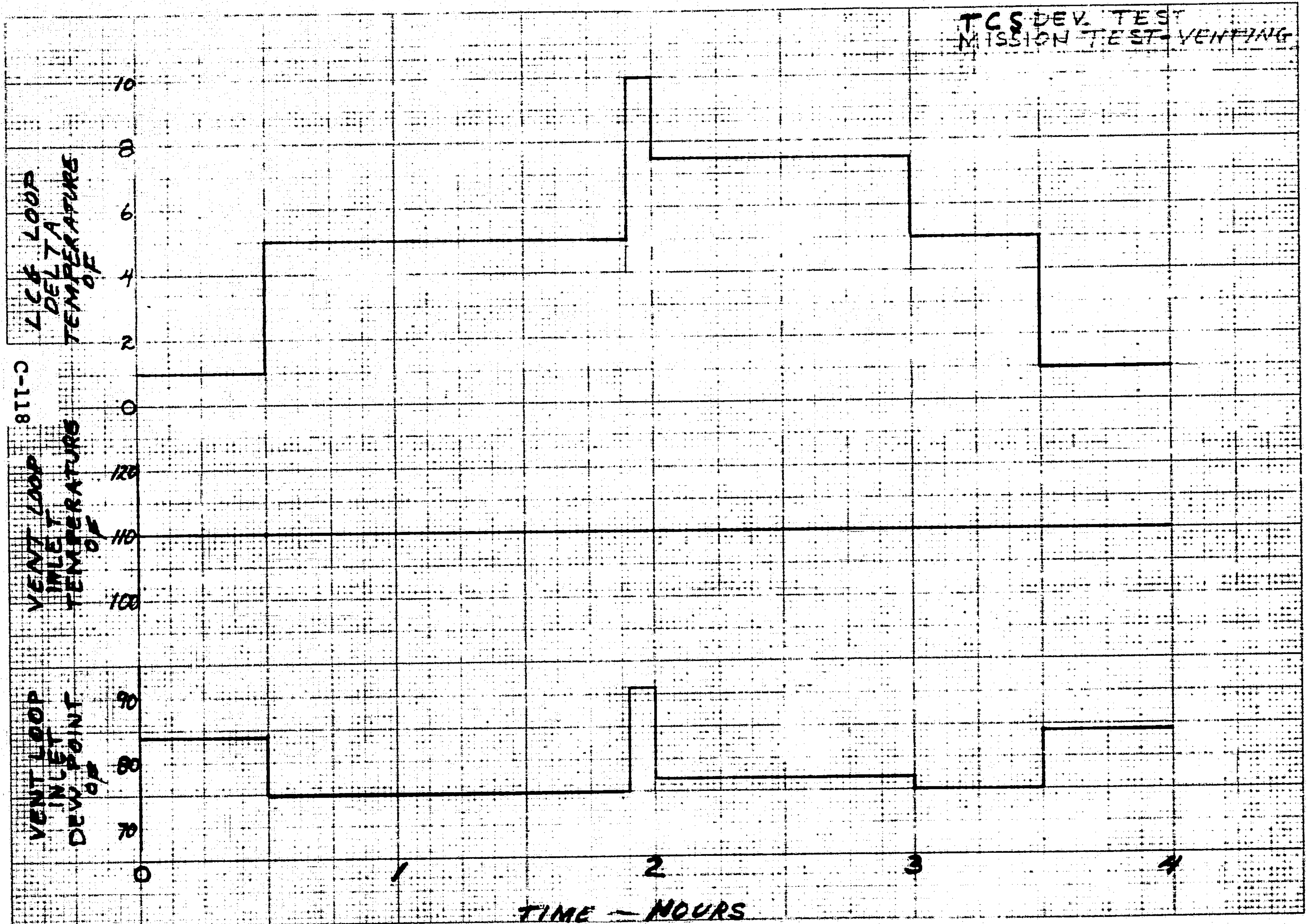


FIGURE 5A - SYSTEM CONNECTIONS

Document No.	Parameter	Minimum Range	Minimum Accuracy
P_1	Pump Inlet Pressure	0-30 Psia	$\pm$ 2 Psi
P_2	Feed Water Reservoir Pressure	0-100 Psia	$\pm$ 1 Psi
P_4	LCG Inlet Pressure	0-30 Psia	$\pm$ .3 Psi
P_5	Chamber Pressure	500-1,000	$\pm$ 3% Angular Def
P_6	Steam Header Pressure	500-1,000	$\pm$ 3% Angular Def
P_7	Vent Outlet Pressure	0-15 Psia	$\pm$ .025 Psi
P_8	Vent Inlet Pressure	0-15 Psia	$\pm$ .025 Psi
P_{10}	Leakage Flow Rate Pressure	0-30 Psia	$\pm$ .3 Psi
P_{11}	Steam Generator Pressure	0-30 Psia	$\pm$ .5 Psia
ΔP_1	LCG ΔP	0-10 Psi (Diff)	$\pm$ .1 Psi
ΔP_2	Vent ΔP	0-10 in H_2O (Diff)	$\pm$ .1 in H_2O
ΔP_3	Slurper ΔP	0-10 in H_2O (Diff)	$\pm$ .1 in H_2O
ΔP_4	Fan ΔP	0-100 in H_2O (Diff)	$\pm$ 1.0 in H_2O
F_1	LCG Flow	.6-5.2 PPM	$\pm$ 2% FS
F_3	Vent Inlet Flow	2-12 PPH @ 3.8 Psia	$\pm$ 2% FS
F_4	Vent Outlet Flow	2-12 PPH @ 3.8 Psia	$\pm$ 2% FS
F_5	Rig Leakage Flow	.001-.016 PPH @ 3.5 Psia	$\pm$ 3°F
T_1	Feed Water Temperature	32-150°F	$\pm$ 3°F
T_2	LCG Inlet Temperature	32-150°F	$\pm$ 3°F
T_3	LCG Outlet Temperature	32-150°F	$\pm$ 3°F
T_4	Vent Inlet Temperature	32-150°F	$\pm$ 3°F
T_5	Vent Outlet Temperature	32-150°F	$\pm$ 3°F
ΔT_1	LCG ΔT	0-20°F	$\pm$ .5°F
ΔT_2	Vent ΔT	0-100°F	$\pm$ 3°F
DP_1	Vent Outlet Dew Point	0-100°F	$\pm$ 3°F
DP_2	Vent Inlet Dew Point	0-100°F	$\pm$ 3°F


TCS DEV. TEST
MISSION TEST-VENTING
LCG LOOP
DELTA
TEMPERATURE
°F
VENT LOOP
INLET
TEMPERATURE
°F
VENT LOOP
INLET
DEW POINT
°F
10
8
6
4
2
0
120
110
100
90
80
70
0
1
2
3
4
TIME — HOURS
FIGURE 6

APPENDIX A

PROCEDURE

FOR

SATURATING WATER

SATURATION PROCEDURE

1.0 INTRODUCTION

This document defines the procedure to be used to saturate water with nitrogen for use in TCS testing.

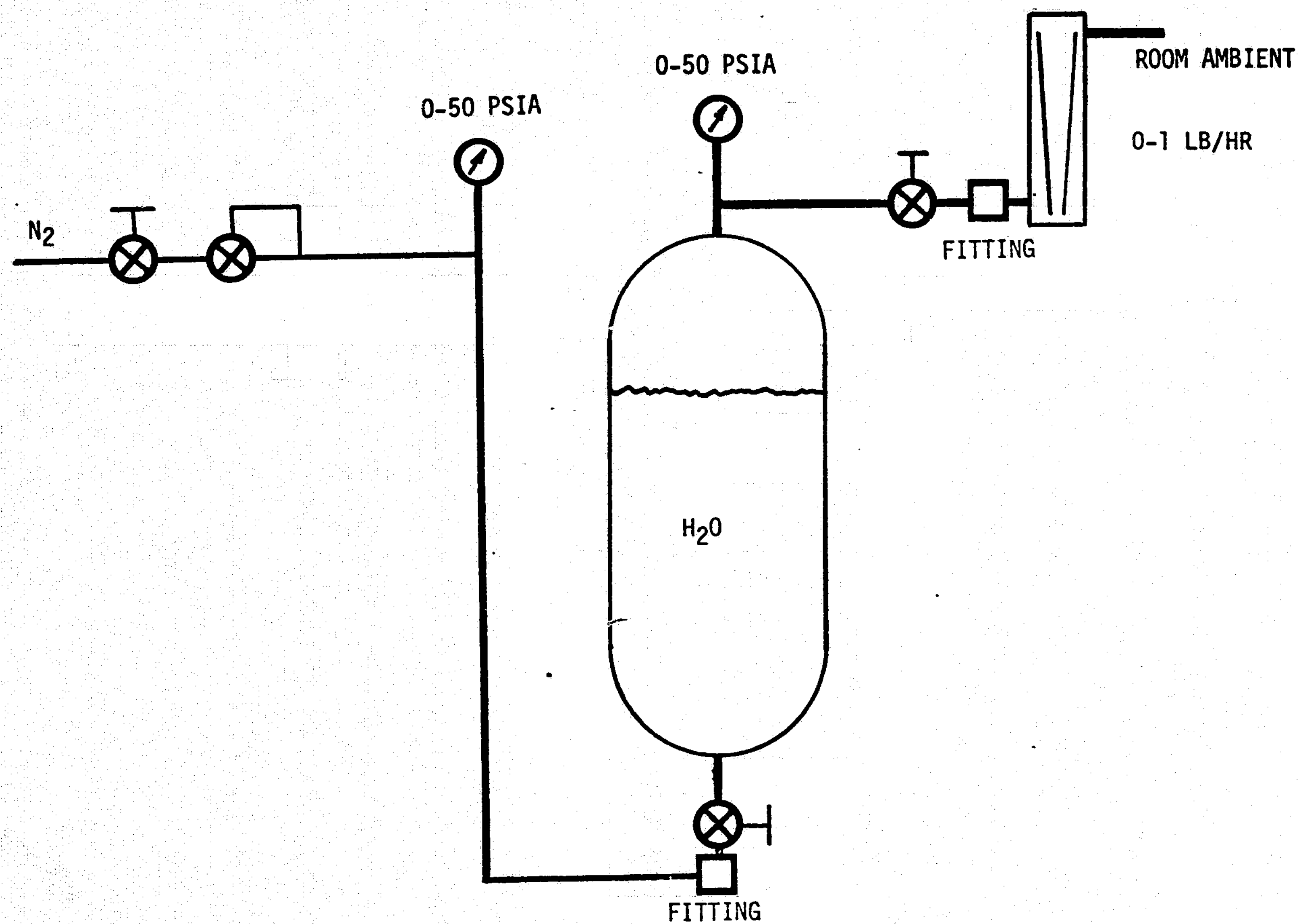
2.0 PROCEDURE

The setup shown in the attached Figure will be used to saturate the water with nitrogen. All lines and fittings must be stainless steel.

The vessel will be charged with at least 50 pounds of water which meets the requirements of SVP 114.

The nitrogen inlet pressure will be set at 35-37 psia, and the flow will be set at .2 lb/hr and will be held for a minimum of 24 hours.

Once the above step has been completed, the pressure in the vessel must be maintained at 35-37 psia. If, at any time, the pressure goes below 33 psia, the preceding step must be repeated.



SETUP FOR SATURATING WATER

EVLSS

THERMAL CONTROL SYSTEM

GAS SEPARATOR

DEVELOPMENT TEST PLAN AND PROCEDURE

TCS-5

PREPARED BY: W Bouchelle DATE: 6-23-75

APPROVED BY: F Goodwin DATE: 6/24/75
ENGINEERING PROGRAM MANAGER

APPROVED BY: R. Woodruff DATE: 6-24-75
QUALITY ASSURANCE

APPROVED BY: M. Rouen by telecon DATE: 6-25-75
NASA

1.0 INTRODUCTION

1.1 Purpose

This test plan and procedure defines the Gas/Liquid Separator, a component of the Thermal Control System, Water Transport Subsystem (WTS) development test program.

1.2 Scope

This document outlines and describes the Gas/Liquid Separator, test conditions and performance criteria. The results of this test program will be included in the monthly progress reports.

1.3 Description of Test Item

The test item is the Gas/Liquid Separator defined by drawing SVSK90475.

2.0 APPLICABLE DOCUMENTS

Drawing

SVSK 90475 Gas/Liquid Separator

Specifications

NASA

MSC-SPEC-C21A Water, High Purity (Potable) Specification for

Hamilton Standard

HS 1550 Pre-Acceptance, Cleaning, Preservation and Handling of Products
SVP 114 Test Fluid Control (High Purity Water)

3.0 TEST SEQUENCE

Sequence	Test	Test Number
1	Examination of Product	5.1
2	Proof Pressure Test	5.2
3	Leakage Test	5.3
4	Separation Verification Test	5.4

4.0 SPECIAL INSTRUCTIONS

4.1 Rigor

The test program shall be conducted under the direction of the cognizant project engineer. Hamilton Standard inspection shall be on a surveillance basis only. Any change to the approved test plan will be coordinated with NASA.

4.2 Reporting

The results of the test program will be included in the monthly progress reports.

4.3 Control of the Test Plan

It shall be the responsibility of the project engineer to insure that the historical log sheets reflect all operations performed on the test article during the test program.

4.4 Equipment Logs (Test Logs)

The test operator shall obtain sufficient data to verify that the test conditions and environmental conditions have been controlled as specified herein. This log will be maintained by the test operator(s). In general, the log shall include, but not be limited to, the following data:

a. Test Title and Procedure Section Number
b. Date
c. Environmental Conditions
d. Test Operator
e. Test Equipment
f. Notes and Comments
g. Test Results

Sample log sheets are included in section 6.

4.5 Environmental Requirements

Unless otherwise specified, testing shall be conducted at local Ambient Temperature and Barometric Pressure. Correction shall be made to provide agreement with the temperature and pressure calibration of the instruments.

4.6 Cleanliness Requirements

The gas used for testing shall be room air. The water used in this test shall be distilled and demineralized per MSC-SPE-C21 with the following exceptions:

1. The water shall contain silver bromide at a concentration of 50-100 PPb.
2. Total solids shall be 3.5 mm/liter maximum.
3. The particulate contamination shall be as follows:

Particle Size Range (Microns)	Maximum Number of Particles Per 100 ML
0-25	Unlimited
25-50	2,100
50-100	100
100-250	4
250	0

Fibers	Maximum Number of Particles Per 100 ML
100-250	1
250-400	1
400	0

4. The pH range shall be 5.5 to 7.5 at 25°C.
5. The following subparagraphs of MSC-SPEC-C21 are not applicable:

   a. 4.1
   b. 4.1.3
   c. 4.1.6
   d. 4.1.7
   e. 4.1.8
   f. 4.1.10

The external surfaces of the test article shall be maintained to a cleanliness level of HS1550C1.

NOTE: Water cleaned per SVP114 meets the requirements above.

5.0 DEVELOPMENT TESTS

5.1 Examination of Product (Log Sheet 6.1)

Examine the item with respect to surface finish, coating, visual defects and compliance with drawing SVSK 90475. Do not disassemble the unit to do a visual examination. Record any visual degradation of unit during the test program. Determine and record the dry weight of the unit.

5.2 Proof Pressure (Log Sheet 6.2)

Set up the unit as shown in Figure 1, and pressurize with nitrogen to a pressure of 54-56 psig. Maintain this pressure for five minutes. There shall be no permanent deformation as a result of this test.

5.3 Leakage Test (Log Sheet 6.3)

Set up the unit as shown in Figure 2, and pressurize with nitrogen to a pressure of 34-36 psig. Immerse unit in water at room temperature and observe for bubbles. There shall be no external leaks.

5.4 Separator Verification

Set up the separator as shown in Figure 3. Between one and one and one half hours after charging the system with water turn on the pump and set a flow of 240 $\pm$ 20 lb/hr. Observe and record the liquid circuit ΔP every hour for 7 hours minimum. After the first seven hours of observation, the unit may be operated for up to 16 hours at a time without recording data. The unit will be operated for a total of 100 hours. Within 30 minutes of flow initiation, air will be injected into the water upstream of the separator at a rate of 35cc/min for a two minute period. Air injection will be repeated at least twice during each day of operation. As a test goal, there shall be no air bubbles present in the line downstream of the separator after each injection of air or during the test run. As a test requirement, degradation of pump performance (head and/or flow) due to the presence of air shall not last more than five seconds.

5.5 Final Drying

After satisfactory completion of the above tests, remove separator from test bench, shake off excess water then dry with gaseous nitrogen as follows: connect a 4-5 psi dry nitrogen supply to the Separator inlet and allow to flow through for 30 minutes or until dry.

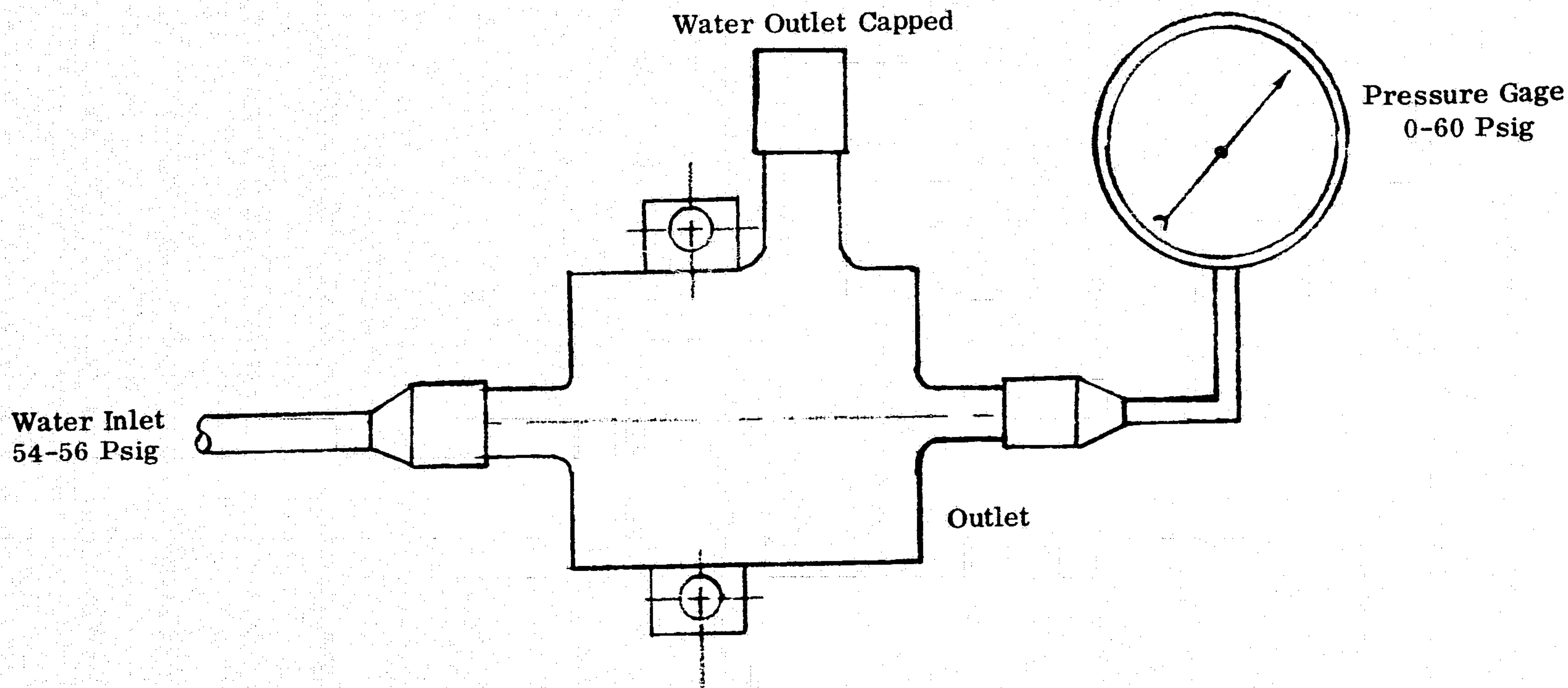

Water Outlet Capped
Pressure Gage
0-60 Psig
Water Inlet
54-56 Psig
Outlet

FIGURE 1

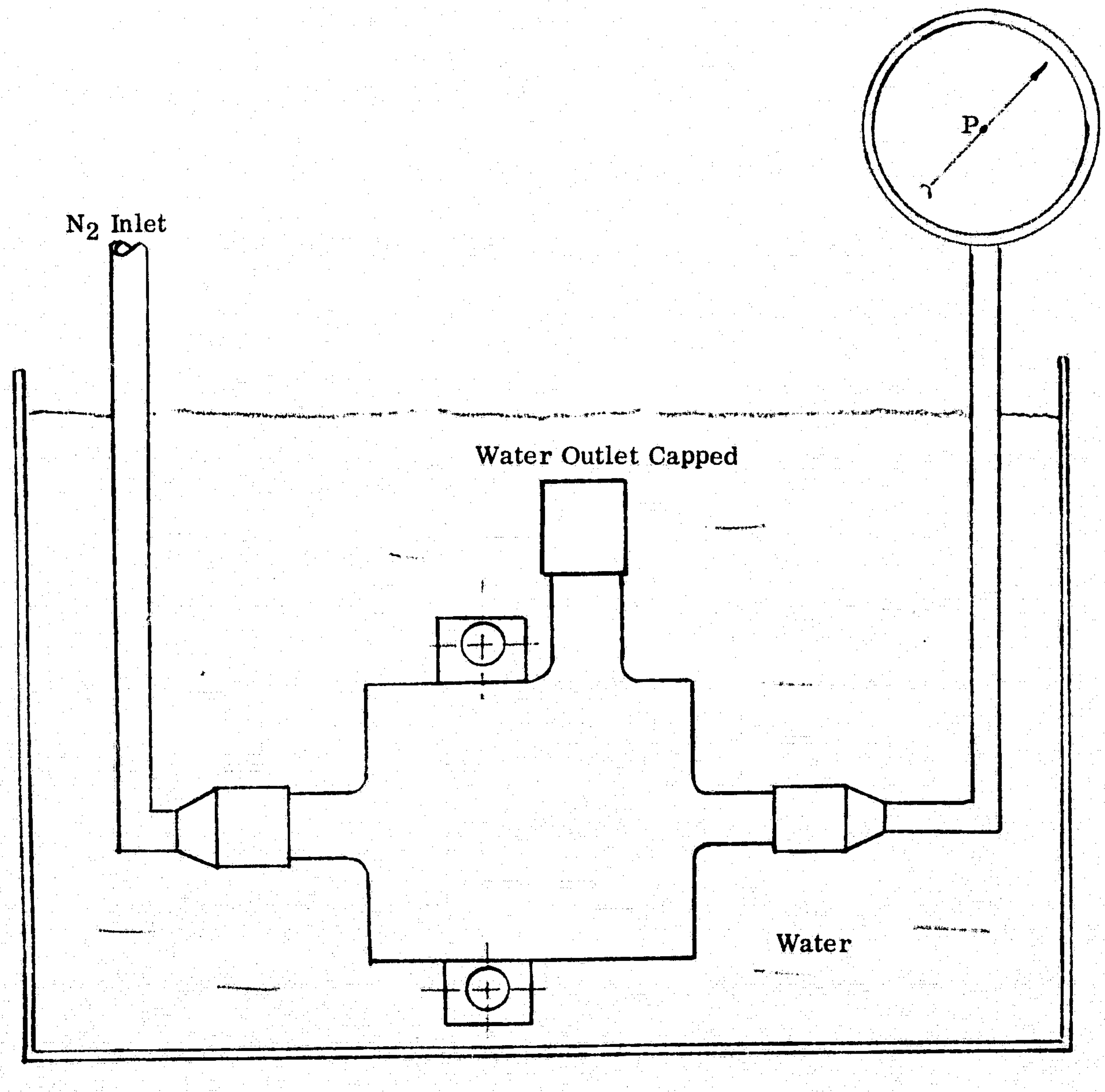


FIGURE 2

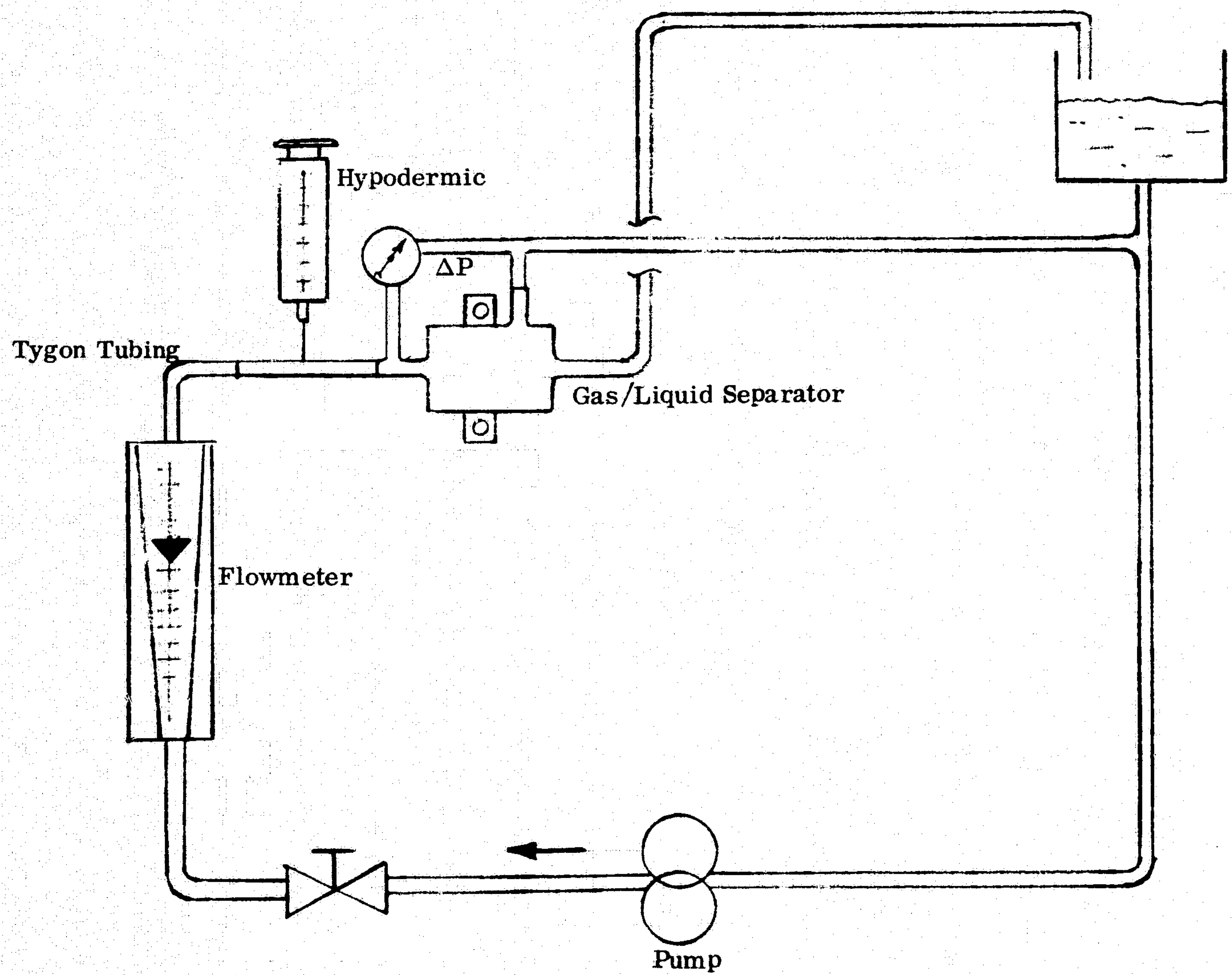

Hypodermic
ΔP
Tygon Tubing
Gas/Liquid Separator
Flowmeter
Pump

FIGURE 3

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST
Examination of Product

TEST ENGINEER

NAME OF RIG
Bench

PROJECT & ENG. ORDER NO.

SHEET OF DATE

TEST PLAN NO. TCS-LCG

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Log Sheet 6.1

Test Number 5.1

Sequence Number

Unit complies with print

Yes No

Record Visual Defects

C-129

Weight (Dry) grams

REMARKS:
Ambient Temperature
Barometric Pressure

18061

SHEET OF DATE

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

Proof Pressure Test

TEST ENGINEER

NAME OF RIG

PROJECT & ENG. ORDER NO.

TEST PLAN NO. TCS-LCG

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Log Sheet 6.2

Test Number 5.2

Sequence Number

		clock time		test time min.		test press. psig

C-130

REMARKS:

18083

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST Leakage Test
TEST ENGINEER
NAME OF RIG
PROJECT & ENG. ORDER NO.

SHEET OF DATE
TEST PLAN NO. TCS-LCG
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Log Sheet 6.3

Test Number 5.3

clock time	test time min.	press. psig

C-131

Freedom from bubbles Yes ________ No ________

REMARKS:
Ambient Temperature
Barometric Pressure

Surface bubbles wiped from unit prior to checking for leakage Yes ________ No ________

18083

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

Separator Verification

TEST ENGINEER

NAME OF RIG

PROJECT & ENG. ORDER NO.

TEST PLAN NO.

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Log Sheet 6.4 Test Number 5.4 Sequence Number

date/ time	water flow lbs/min	air inject time	line free of bubbles yes	no	ambient temp.	ambient bar. pr.	ΔP in H_2O

C-132

REMARKS:

18085

EVLSS

THERMAL CONTROL SYSTEM

VEHICLE UMBILICAL CONNECTOR

DEVELOPMENT TEST PLAN AND PROCEDURE

TCS-6

PREPARED BY: W. Bouchelle DATE: 6-23-75

APPROVED BY: F Goodwin DATE: 6/24/75
ENGINEERING PROGRAM MANAGER

APPROVED BY: R. Woodruff DATE: 6/24/75
QUALITY ASSURANCE

APPROVED BY: M. Rouen by telecon DATE: 6-25-75
NASA

1.0 INTRODUCTION

1.1 Purpose

The test plan and procedure defines the Thermal Control System Vehicle Umbilical Connector development test program.

1.2 Scope

This document outlines and describes the item to be tested, test conditions and objectives and performance criteria. The results of this test program will be included in the monthly progress reports.

1.3 Description of Test Item

The test item is the Thermal Control System Vehicle Umbilical Connector which is defined schematically in Figures 1 and 2. The test unit is defined by drawing SVSK 90196.

2.0 APPLICABLE DOCUMENTS

Drawings

SVSK 90196	Water Connector

Standards

MIL-P-27401	Propellant, Pressurizing Agent, Nitrogen

Specifications

NASA

MSC-SPEC-C21A	Water, High Purity (Potable) Specification for

Hamilton Standard

HS 1550	Pre Acceptance, Cleaning, Preservation and Handling of Products
SVP 114	Test Fluid Control (High Purity Water)

3.0 TEST SEQUENCE

Sequence	Test	Test Number
1	Examination of Product	5.1
2	Proof Pressure Test	5.2
3	Cross Leakage Test	5.3
4	External Leakage Test	5.4
5	Force to Connect	5.5
6	Delta P Coupled	5.6
7	Delta P Uncoupled	5.7

4.0 SPECIAL INSTRUCTIONS

4.1 Rigor

The test program shall be conducted under the direction of the cognizant project engineer. Hamilton Standard inspection shall be on a surveillance basis only. Any changes to the approved test plan will be coordinated with NASA.

4.2 Reporting

The results of the test program will be included in the monthly progress reports.

4.3 Control of the Test Plan

It shall be the responsibility of the project engineer to insure that the historical log sheets reflect all operations on the test article during the test program.

4.4 Equipment Logs (Test Logs)

The test operator shall obtain sufficient data to verify that the test conditions and environmental conditions have been controlled as specified herein. This log will be maintained by the test operator(s). In general, the log shall include, but not be limited to, the following data:

a. Test Title and Procedure Section Number
b. Date
c. Environmental Conditions
d. Test Operator
e. Test Equipment
f. Notes and Comments
g. Test Results

Sample log sheets are included in Section 6.

4.5 Environmental Requirements

Unless otherwise specified, testing shall be conducted at local Ambient Temperatures and Barometric Pressure. Correction shall be made to provide agreement with the temperature and pressure calibration of the instruments.

4.6 Cleanliness Requirements

Nitrogen conforming to MIL-P-27401 shall be used during testing specified within this document. This gas shall be filtered through a 15 micron absolute filter. The water used during these tests shall be distilled and demineralized per MSC-SPEC-C21 with the following exceptions:

4.6 (Continued)

1. The water shall contain silver bromide at a concentration of 50-100 PPb.
2. Total solids shall be 3.5 mm/liter maximum.
3. The particulate contamination shall be as follows:

Particle Size Range (Microns)	Maximum Number of Particles Per 100 ML
0-25	Unlimited
25-50	2,100
50-100	100
100-250	4
250	0

Fibers	Maximum Number of Particles Per 100 ML
100-250	1
250-400	1
400	0

4. The PH range shall be 5.5 to 7.5 at 25°C.
5. The following subparagraphs of MSC-SPEC-C21 are not applicable:
   a. 4.1
   b. 4.1.3
   c. 4.1.6
   d. 4.1.7
   e. 4.1.8
   f. 4.1.10

4.6 (Continued)

The external surfaces of the test article shall be maintained to a cleanliness level of HS 1550Cl.

NOTE: Water cleaned per SVP 114 meets the requirements above.

5.0 DEVELOPMENT TESTS

5.1 Examination of Product (Log Sheet 6.1)

Examine the item with respect to surface finish, coating, visual defects and compliance with drawing SVSK 90196. Do not disassemble the unit to do a visual examination. Record any visual degradation of unit during the test program. Determine and record the dry weights of the unit.

5.2 Proof Pressure (Log Sheet 6.2)

Set up the unit as shown in Figure 3 and pressurize the liquid circuit with nitrogen to a pressure of 57 ± 2 psig. Maintain this pressure for five minutes. Couple the halves and repeat the test. There shall be no permanent deformation as a result of this test.

5.3 Cross Leakage Test (Log Sheet 6.3)

Set up the unit as shown in Figure 4 and pressurize the water inlet side to 5 ± .5 psig. The water flow from the outlet ports shall not exceed 5 lb/hr.

5.4 External Leakage Test (Log Sheet 6.4)

Set up connectors as shown in Figure 5 and pressurize to 5 ± .5 psig for 30 minutes. There shall be no evidence of water leakage.

5.4 (Continued)

Uncouple the connectors and repeat the above test. There shall be no evidence of water leakage.

5.5 Force to Connect (Log Sheet 6.5)

Set up the connector as shown in Figure 6, pressurize to 25 psig, and couple the connector. The force to connect shall not exceed 20 lbs.

5.6 Delta P Coupled (Log Sheet 6.6)

Set up the connectors as shown in Figure 7 and record the delta P between the back pack inlet port and the umbilical inlet port at water flows of 50, 100, 150, 200, 240 lb/hr. The test shall be repeated with water flowing from the umbilical outlet port to the back pack outlet port. The delta P in either circuit shall not exceed .75 psi at 240 lb/hr.

5.7 Delta P Uncoupled (Log Sheet 6.6)

Set up the back pack half as shown in Figure 8 and record the delta P between the back pack inlet port and the back pack outlet port water flows of 50, 100, 150, 200, and 240 lb/hr. The delta P shall not exceed .25 psi at 240 lb/hr.

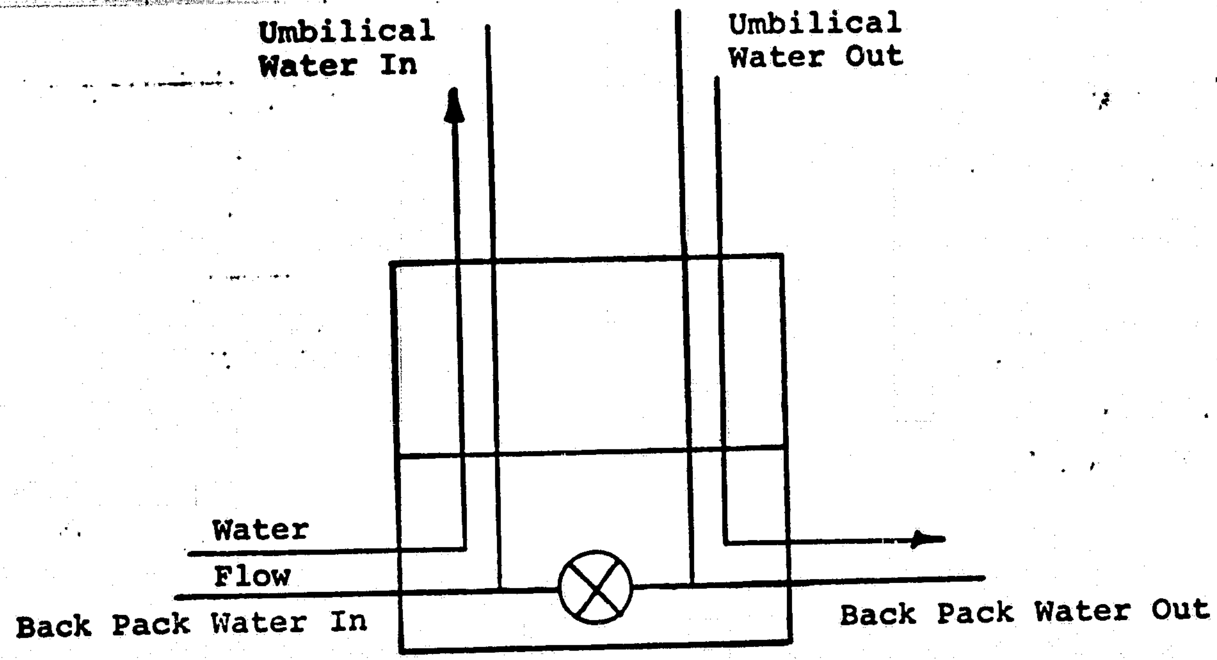


Figure 1
Coupled

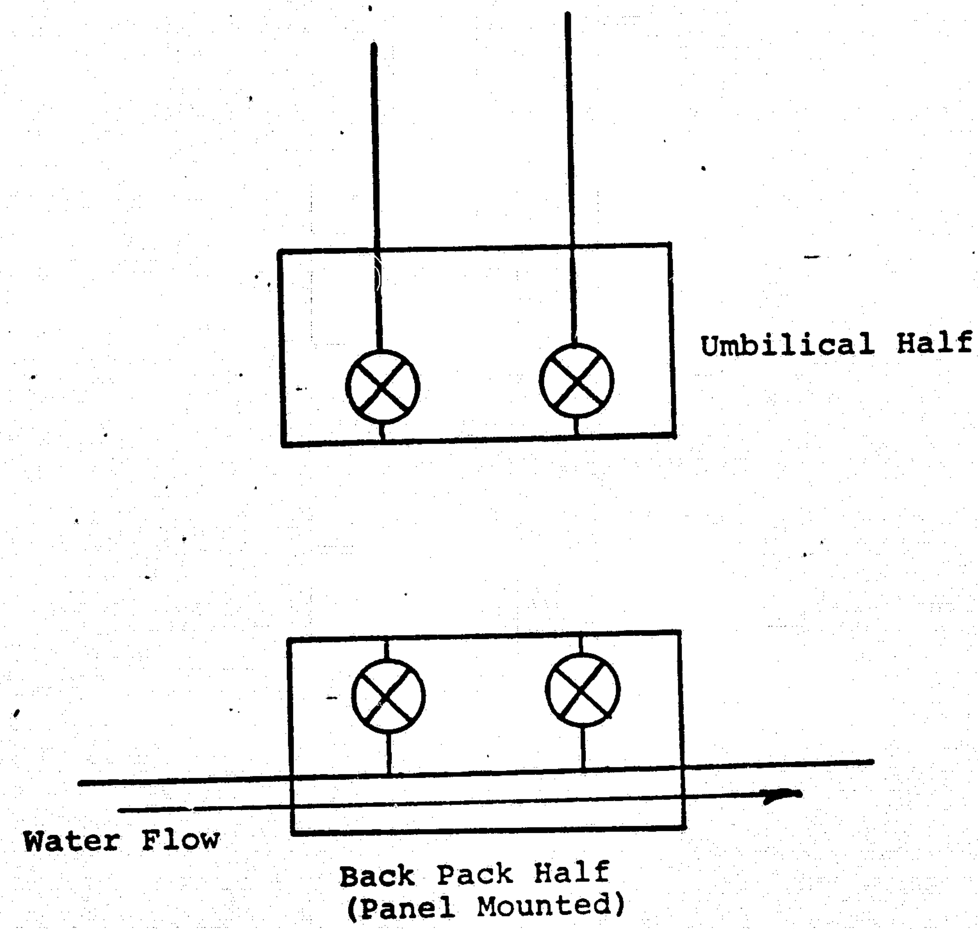
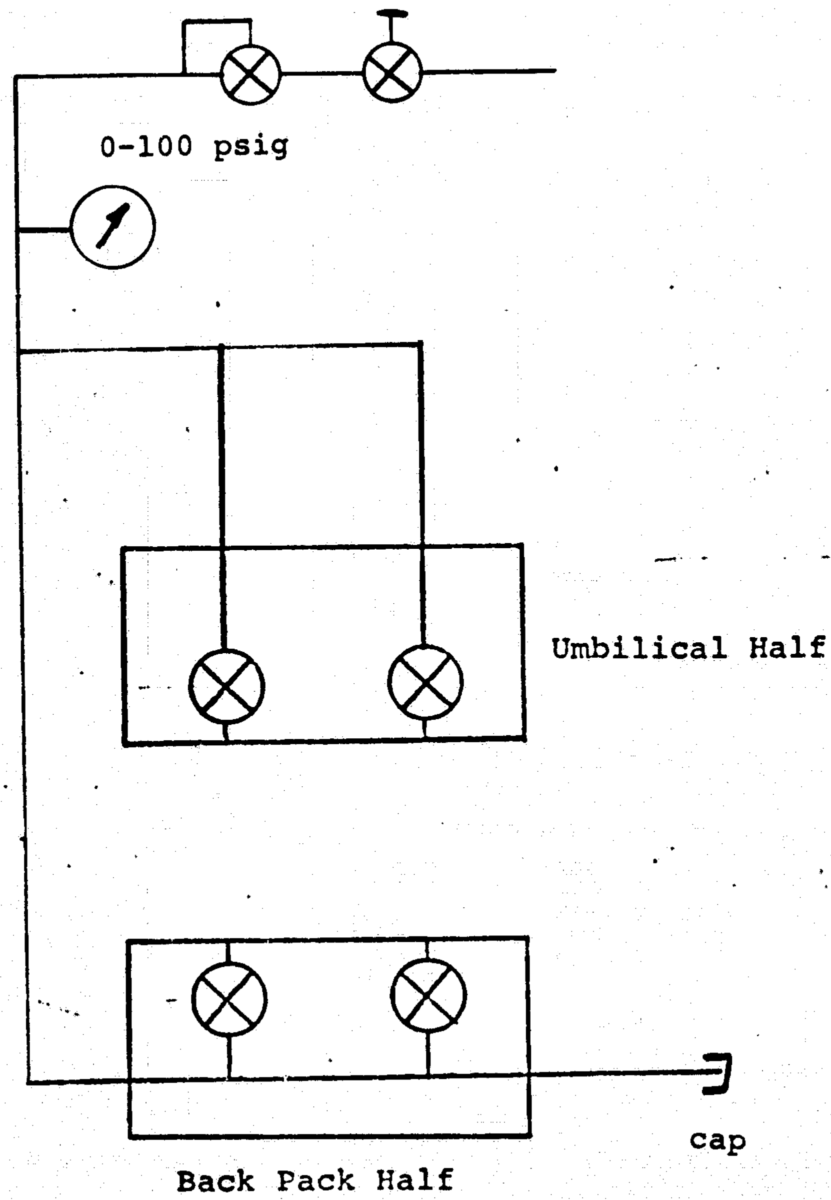


Figure 2
Uncoupled



Proof Pressure Test

Figure 3

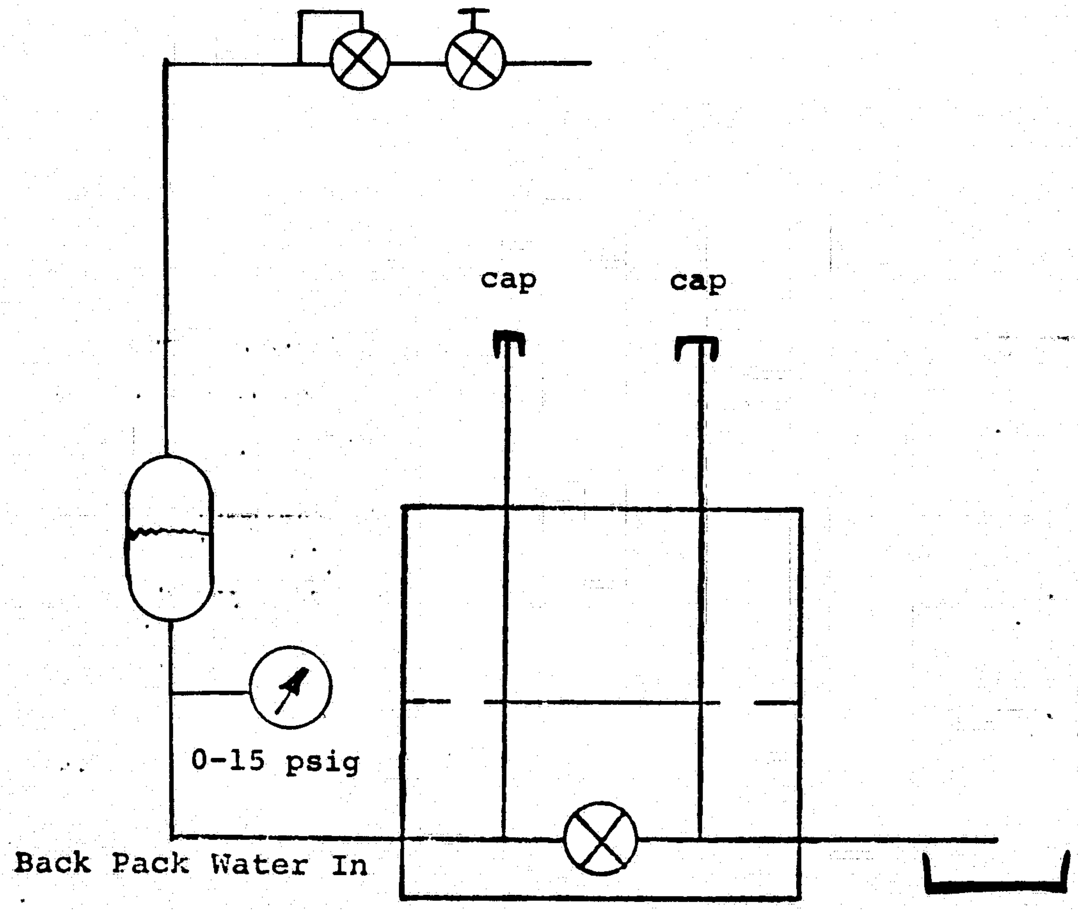


Figure 4

Cross Leakage Test

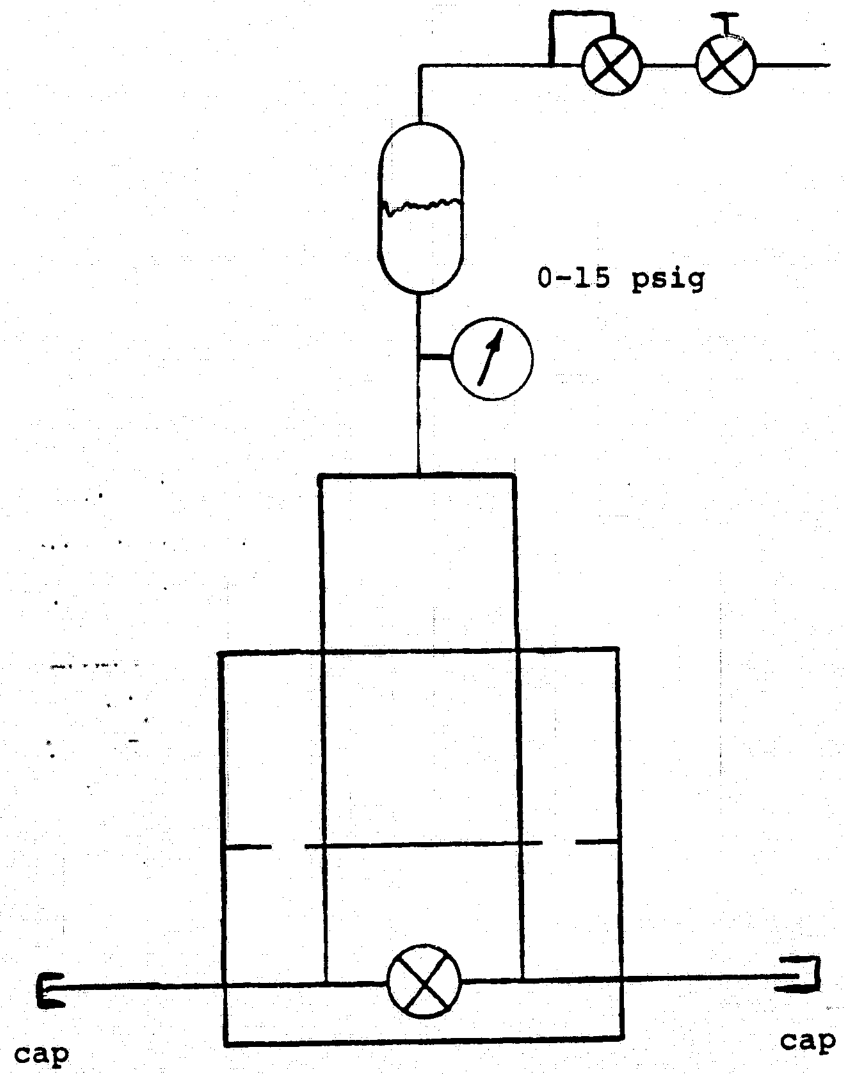


Figure 5

External Leakage Test

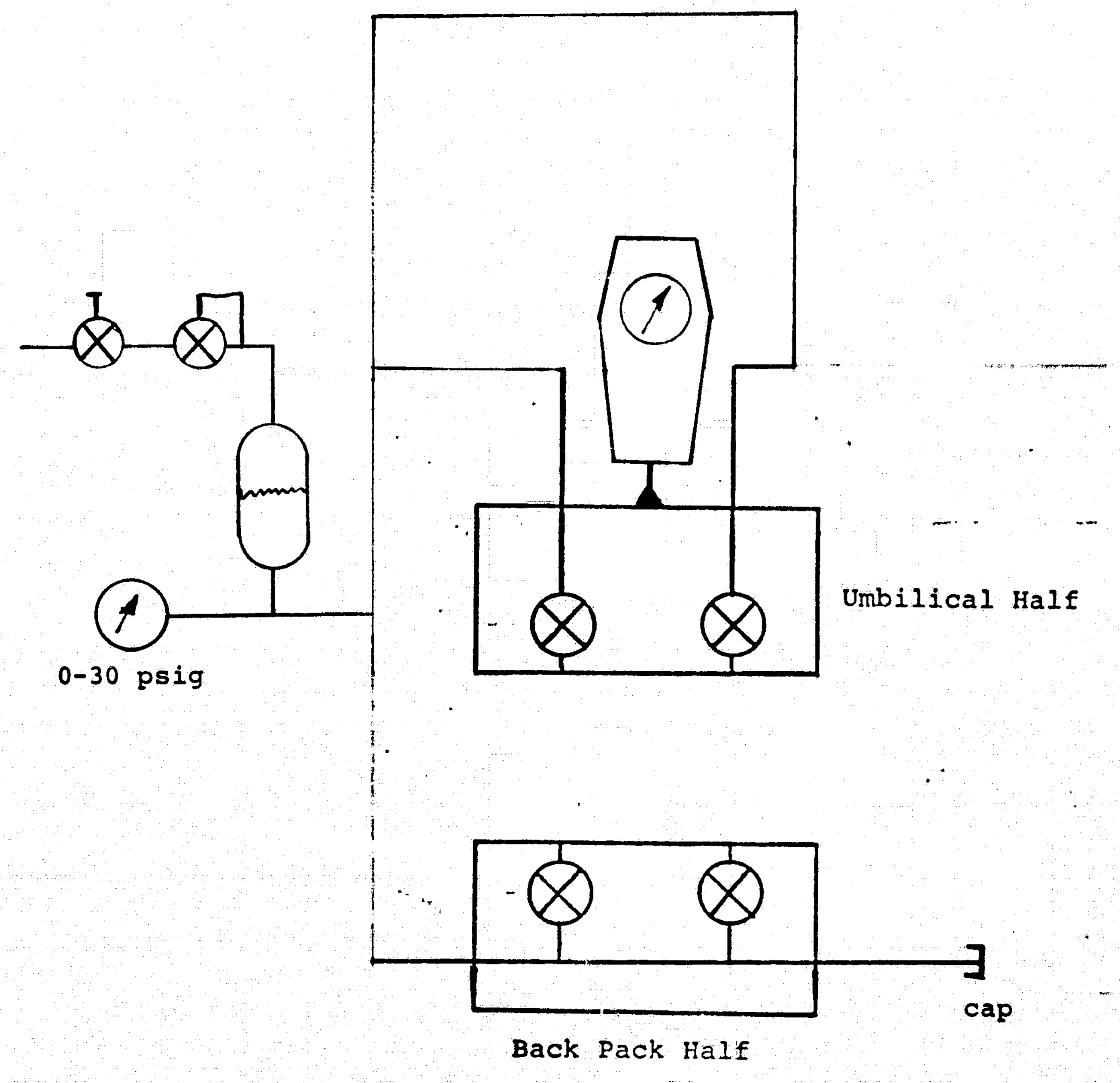


Figure 6

Force to Connect

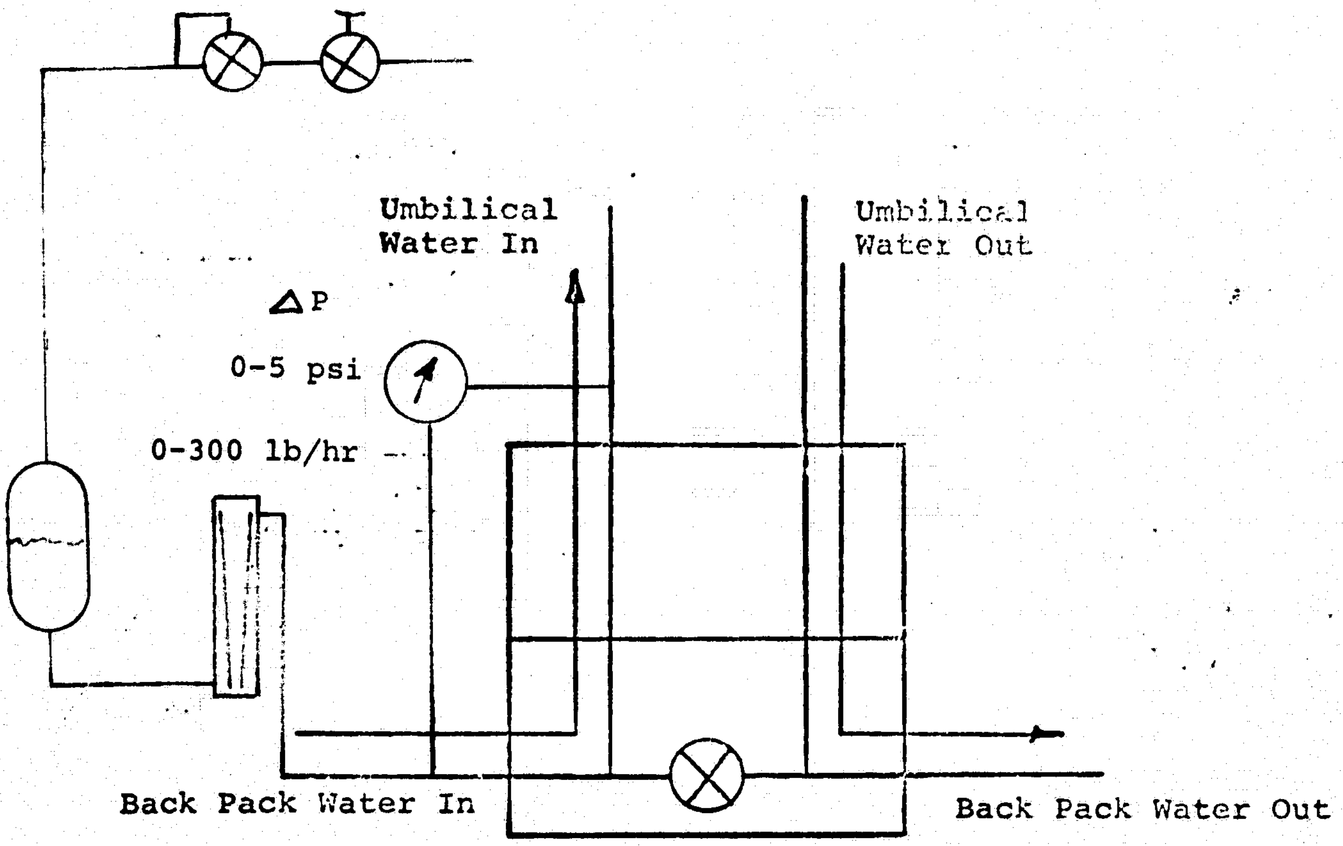


Figure 7

Pressure Drop Coupled

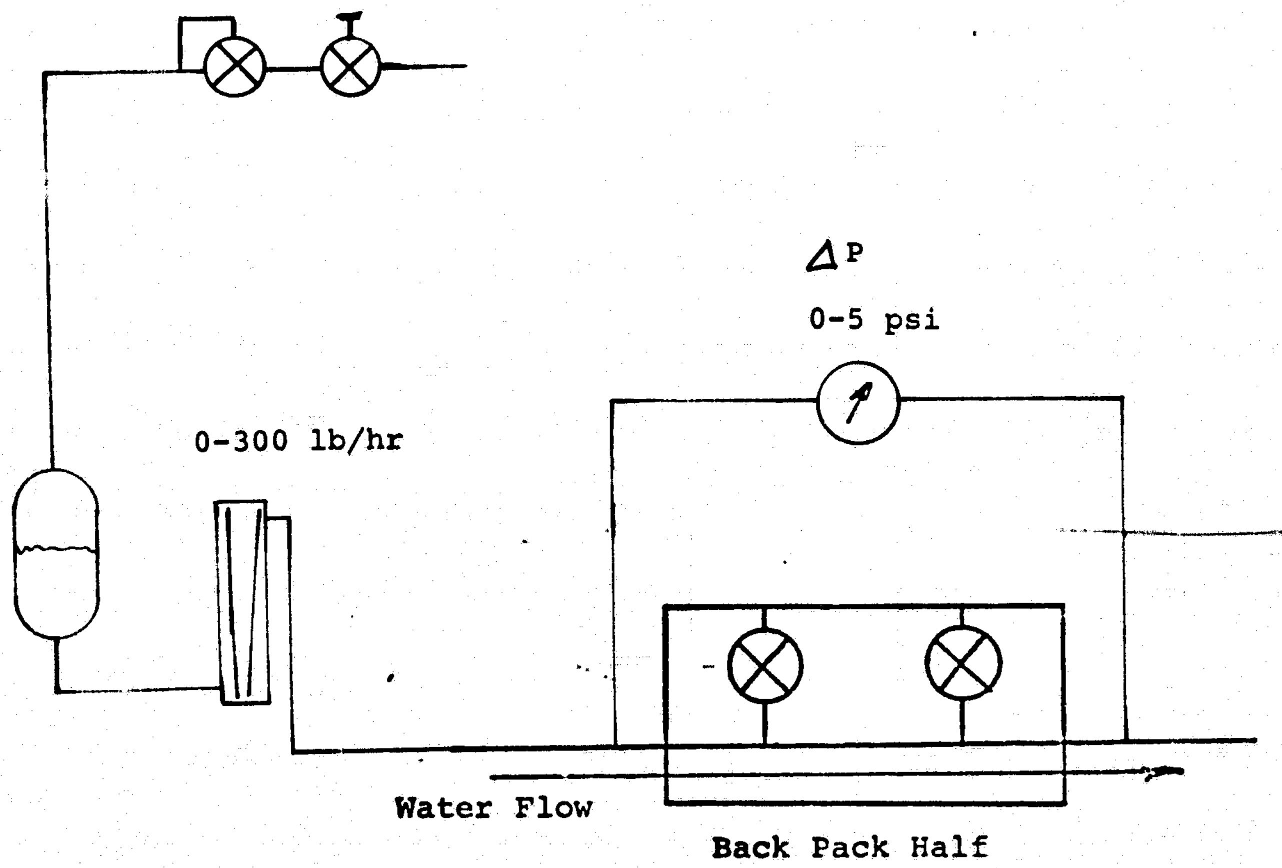


Figure 8

Pressure Drop Uncoupled

HSF-175.1A 1/66

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	Examination of Product
TEST ENGINEER	
NAME OF RIG	Bench
PROJECT & ENG. ORDER NO.	
SHEET	OF
DATE	
TEST PLAN NO.	TCS-6
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Log Sheet 6.1 | Test Number 5.1 | Sequence Number

Unit complies with print | Yes | No

Record Visual Defects

Weight (Dry) grams

C-147

REMARKS:

Ambient Temperature
Barometric Pressure

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Proof Pressure Test

TEST ENGINEER

NAME OF RIG

PROJECT & ENG. ORDER NO.

SHEET   OF   DATE

TEST PLAN NO. TCS-6

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Log Sheet 6.2   Test Number 5.2   Sequence Number

		clock time	test time min.	test press. psig

C-148

REMARKS:

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	CROSS Leakage Test
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	
SHEET	
OF	
DATE	
TEST PLAN NO.	TCS-6
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Log Sheet 6.3

Test Number 6.3

Clock time	Press. psig	Water flow lb/hr

C-149

REMARKS:
Ambient Temperature
Barometric Pressure

HSF-173.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST Leakage Test

TEST ENGINEER

NAME OF RIG

PROJECT & ENG. ORDER NO.

SHEET OF DATE

TEST PLAN NO. TCS-6

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Log Sheet 6.4

Test Number 5.4

clock time	test time min.	press. psig

C-150

Freedom from leakage Yes No

REMARKS:

Ambient Temperature
Barometric Pressure

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	Force to Connect
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	
SHEET ___ OF ___	DATE
TEST PLAN NO.	TCS-6
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Log sheet 6.5

Test Number 5.5

clock time	pressure psig	Force to Connect 16S

C-151

REMARKS:

Ambient Temperature
Barometric Pressure

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	Pressure Drop
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	
SHEET	
OF	
DATE	
TEST PLAN NO.	TCS-6
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Log Sheet 6.6

Test Number 5.6 and 5.7

clock time	flow lb/hr	DP psi

C-152

REMARKS:

APPENDIX D

HEAT REJECTION SUBSYSTEM AND THERMAL CONTROL SYSTEM PERFORMANCE TEST RESULTS

1.0 This Appendix contains the performance test results for the two sublimators and the Thermal Control System. Tables D-1 through D-5 contain the data obtained with the first sublimator using plate number 1. Tables D-6 through D-9 contain the data obtained with the first sublimator using plate number 2. The data obtained with the second sublimator is contained in Tables D-10 through D-11, and the data obtained when testing the complete TCS is contained in Tables D-12 through D-14.

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OF POOR QUALITY

TABLE D-1
FIRST SUBLIMATOR
STEADY STATE TEST RESULTS SUMMARY

POROUS PLATE NUMBER 1

	LIQUID LOOP				GAS LOOP						Total Heat Load Watts (Btu/Hr)
	T_{in} °C (°F)	T_{out} °C (°F)	Flow kg/sec (lb/hr)	ΔP KPa (psi)	T_{in} °C (°F)	T_{out} °C (°F)	DP_{in} °C (°F)	DP_{out} °C (°F)	Flow m^3/sec (cfm)	ΔP Pa (in H_2O)	
TEST RESULTS	1.4 (34.5)	.56 (33)	3.03×10^{-2} (240)	5.4 (.79)	21.4 (70.5)	2.78 (37.3)	10.56 (51)	1.11 (34)	2.6×10^{-3} (5.51)	50 (.2)	147 (500)
	1.7 (35)	1.1 (34)	3.02×10^{-2} (240)	5.4 (.79)	32.2 (90)	2.0 (35.5)	18.89 (66)	1.11 (34)	2.7×10^{-3} (5.86)	100 (.4)	208 (710)
	2.22 (36)	1.67 (35)	3.0×10^{-2} (238)	5.1 (.74)	43.33 (110)	1.11 (34)	33.6 (92.5)	1.67 (35)	3.3×10^{-3} (7.05)	124 (.5)	372 (1,270)
	5.56 (42)	2.5 (36.5)	3.06×10^{-2} (243)	4.3 (.62)	21.67 (71)	4.44 (40)	10.28 (50.5)	2.22 (36)	2.6×10^{-3} (5.55)	37 (.15)	434 (1,480)
	5.28 (41.5)	2.5 (36.5)	3.03×10^{-2} (240)	4.9 (.72)	31.95 (89.5)	2.78 (37.3)	18.1 (64.5)	2.5 (36.5)	2.8×10^{-3} (5.9)	100 (.4)	434 (15,20)
	6.67 (44)	3.89 (39)	3.03×10^{-2} (240)	4.6 (.66)	43.89 (111)	2.22 (36)	33.1 (91.5)	2.78 (37.1)	3.3×10^{-3} (7.1)	137 (.55)	645 (2,200)
	10.56 (51)	5.0 (41)	3.06×10^{-2} (243)	4.6 (.65)	20.84 (69.5)	5.84 (42.5)	10.56 (51)	4.2 (39.5)	2.6×10^{-3} (5.52)	37 (.15)	748 (2,550)
	10.56 (51)	5.0 (41)	3.06×10^{-2} (243)	4.4 (.64)	31.67 (89)	4.44 (40)	18.1 (64.5)	4.44 (40)	2.7×10^{-3} (5.84)	100 (.4)	798 (2,720)
	12.5 (54.5)	6.67 (44)	3.0×10^{-2} (238)	4.2 (.61)	42.77 (109)	4.72 (40.5)	3.33 (92)	4.72 (40.5)	3.1×10^{-3} (6.7)	112 (.45)	1,003 (3,420)
SPEC	12.22 (54) inlet	7.22 (45) max. out	3.03×10^{-2} (240) nominal	5.0 (.728 psi) max at T_{in} = 12.22°C (54°F)	43.33 (110) inlet	10.00 (50) max. outlet	32.78 (91) inlet	10.0 (50) max. outlet	2.7×10^{-3} (5.7 cfm) nominal	697 (2.8) max at 43.33 (110°F) and DP = 32.8°C (91°F)	909 (3,100) Max Load

TABLE D-2
FIRST SUBLIMATOR
MISSION TEST (VENTING) RESULTS SUMMARY

POROUS PLATE NUMBER 1

	LIQUID LOOP				GAS LOOP					
	Tin °C (°F)	Tout °C (°F)	Flow Kg/sec (lb/hr)	ΔP KPa (psi)	Tin °C (°F)	Tout °C (°F)	DPin °C (°F)	DPout °C (°F)	Flow m^3/sec (cfm)	ΔP Pa (in H_2O)
MISSION CYCLE NUMBER 1	.84 (33.5)	.84 (33.5)	2.96×10^{-2} (235)	5.1 (.74)	38.9 (102)	3.3 (38)	28.9 (83.5)	3.1 (37.5)	33.8×10^{-4} (7.16)	111 (.45)
	.28 (32.5)	.56 (33)	2.95×10^{-2} (234)	5.1 (.74)	42.2 (108)	3.9 (39)	30.00 (86)	3.3 (38)	30.6×10^{-4} (6.49)	99 (.4)
	6.4 (43.5)	3.3 (38)	3.03×10^{-2} (240)	9.9 (.71)	40.5 (105)	5.6 (42)	23.4 (73.5)	4.7 (40.5)	32.9×10^{-4} (6.98)	111 (.45)
	5.8 (42.5)	3.1 (37.5)	3.06×10^{-2} (243)	4.9 (.71)	41.7 (107)	5.0 (41)	23.4 (73.5)	4.2 (39.5)	32.9×10^{-4} (6.99)	124 (.5)
	11.7 (53)	6.11 (43)	3.09×10^{-2} (245)	4.4 (.64)	42.8 (109)	6.7 (44)	32.22 (90)	6.7 (44)	36.2×10^{-4} (7.68)	136 (.55)
	8.9 (48)	4.4 (40)	3.09×10^{-2} (245)	4.7 (.68)	43.3 (110)	5.6 (42)	25 (77)	4.7 (40.5)	31.6×10^{-4} (6.7)	124 (.5)
	9.2 (48.5)	4.7 (40.5)	3.06×10^{-2} (243)	4.4 (64)	43.3 (110)	5.0 (41)	26.11 (79)	4.7 (40.5)	33.9×10^{-4} (7.2)	124 (.5)
	3.1 (37.5)	1.9 (35.5)	2.99×10^{-2} (237)	4.9 (.71)	43.9 (111)	3.9 (39)	28.6 (83.5)	3.3 (38)	34.4×10^{-4} (7.29)	111 (.45)
	2.2 (36)	1.67 (35)	2.99×10^{-2} (232)	5.0 (.73)	43.9 (111)	3.9 (39)	28.3 (83)	3.3 (38)	35.2×10^{-4} (7.45)	136 (.55)

Time to start up ≈ 20 Seconds
Time to Shutdown ≈ 4 Minutes

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TABLE D-3
FIRST SUBLIMATOR
MISSION TEST (VENTING) RESULTS SUMMARY
POROUS PLATE NUMBER 1

	LIQUID LOOP				GAS LOOP					
	T_{in} °C (°F)	T_{out} °C (°F)	Flow Kg/sec (lb/hr)	ΔP Kpa (psi)	T_{in} °C (°F)	T_{out} °C (°F)	DP_{in} °C (°F)	DP_{out} °C (°F)	Flow m^3/sec (cfm)	ΔP Pa (in H_2O)
MISSION CYCLE 2	1.9 (35.5)	1.4 (34.5)	3.0×10^{-2} (238)	5.0 (.73)	43.3 (110)	3.3 (38)	29.2 (84.5)	1.9 (35.5)	33.7×10^{-4} (7.18)	124 (.5)
	2.2 (36.4)	1.7 (35)	3.0×10^{-2} (238)	5.0 (.73)	43.3 (110)	3.3 (38)	29.4 (85)	2.2 (36)	32.4×10^{-4} (6.9)	136 (.55)
	5.3 (41.5)	2.8 (37)	2.99×10^{-2} (237)	4.6 (.66)	42.8 (109)	2.78 (37)	23 (73.5)	2.8 (37)	33.4×10^{-4} (7.1)	136 (.55)
	5.3 (41.5)	2.8 (37)	2.98×10^{-2} (236)	4.6 (.65)	42.8 (109)	3.1 (37.5)	23.6 (74.5)	2.8 (37)	34.8×10^{-4} (7.4)	149 (.6)
	10.8 (51.5)	5.6 (42)	3.0×10^{-2} (238)	3.2 (.47)	43.9 (111)	5.0 (41)	32.5 (90.5)	3.9 (39)	34.3×10^{-4} (7.3)	149 (.6)
	8.1 (46.5)	4.2 (39.5)	2.98×10^{-2} (236)	3.4 (.49)	43.3 (110)	4.4 (40)	25 (77)	3.6 (38.5)	35.3×10^{-4} (7.5)	149 (.6)
	8.6 (47.5)	4.4 (40)	2.95×10^{-2} (234)	4.0 (.58)	43.3 (110)	3.9 (39)	25.6 (76)	3.6 (38.5)	34.8×10^{-4} (7.4)	149 (.6)
	5.6 (42)	2.8 (37)	2.95×10^{-2} (234)	4.3 (.63)	43.3 (110)	2.8 (37)	24.1 (75.5)	2.6 (36.5)	34.3×10^{-4} (7.3)	149 (.6)
	2.2 (36)	1.7 (35)	3.05×10^{-2} (242)	5.2 (.75)	43.3 (110)	2.8 (37)	29.4 (85)	2.6 (36.5)	35.3×10^{-4} (7.5)	149 (.6)

Time to Start up = 25 Seconds
Time to Shutdown = 4 Minutes

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TABLE D-4
FIRST SUBLIMATOR
MISSION TEST (VENTING) RESULTS SUMMARY
POROUS PLATE NUMBER 1

	LIQUID LOOP				GAS LOOP					
	T_{in} °C (°F)	T_{out} °C (°F)	Flow Kg/sec (lb/hr)	ΔP Kpa (psi)	T_{in} °C (°F)	T_{out} °C (°F)	DP_{in} °C (°F)	DP_{out} °C (°F)	Flow m^3/sec (cfm)	ΔP Pa (in H_2O)
MISSION CYCLE 3	3.9 (39)	2.2 (36)	2.96×10^{-2} (235)	4.4 (.64)	44.4 (112)	2.2 (36)	29.4 (84.5)	2.6 (36.5)	30.9×10^{-4} (6.58)	124 (.5)
	5.3 (41.5)	2.8 (37)	2.96×10^{-2} (235)	4.3 (.63)	43.6 (110.5)	3.3 (38)	23.6 (74.5)	3.9 (39)	31.3×10^{-4} (6.66)	111 (.45)
	6.1 (43)	3.1 (37.5)	2.96×10^{-2} (234)	4.2 (.62)	43.3 (110)	2.2 (36)	25 (77)	3.9 (39)	30.5×10^{-4} (6.48)	111 (.45)
	10.6 (51)	5.6 (42)	2.96×10^{-2} (234)	3.8 (.55)	44.4 (112)	3.9 (39)	32.8 (91)	5 (41)	30.9×10^{-4} (6.57)	124 (.5)
	8.3 (47)	4.1 (39.5)	2.93×10^{-2} (232)	3.9 (.57)	44.4 (112)	3.3 (38)	25.3 (77.5)	4.1 (39.5)	31.3×10^{-4} (6.67)	124 (.5)
	8.9 (48)	4.4 (40)	2.93×10^{-2} (232)	3.9 (.57)	43.9 (111)	3.3 (38)	25 (77)	4.7 (40.5)	31.1×10^{-4} (6.61)	136 (.55)
	6.4 (43.5)	3.3 (38)	2.93×10^{-2} (232)	4.2 (.62)	43.9 (111)	2.8 (37)	24.1 (75.5)	4.1 (39.5)	31.1×10^{-4} (6.61)	124 (.5)
	2.8 (37)	1.9 (35.5)	$2.96.10^{-2}$ (234)	4.2 (.65)	43.9 (111)	1.1 (34)	29.2 (84.5)	1.4 (34.5)	30.6×10^{-4} (6.5)	136 (.55)

Time to Start up ≒ 20 Seconds
Time to Shut down ≒ 4 Minutes

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TABLE D-5
FIRST SUBLIMATOR
MISSION TEST (NON VENTING) RESULTS SUMMARY

LIQUID LOOP				GAS LOOP					
T_{in} °C (°F)	T_{out} °C (°F)	Flow Kg/sec (lb/hr)	ΔP Kpa (psi)	T_{in} °C (°F)	T_{out} °C (°F)	DP_{in} °C (°F)	DP_{out} °C (°F)	Flow m^3/sec (cfm)	ΔP Pa (in H_2O)
6.9 (44.5)	8.6 (47.5)	2.96×10^{-2} (235)	3.7 (.54)	43.9 (111)	8.9 (48)	28.9 (84)	8.9 (48)	33.8×10^{-4} (7.2)	149 (.6)
5.3 (41.5)	7.5 (45.5)	2.95×10^{-2} (234)	3.7 (.54)	44.4 (112)	8.3 (47)	29.7 (85.5)	8.3 (47)	33.8×10^{-4} (7.2)	149 (.6)
5.0 (41)	6.4 (43.5)	2.94×10^{-2} (233)	.37 (.54)	43.3 (110)	6.7 (44)	23.9 (75)	7.2 (45)	32.4×10^{-4} (6.9)	136 (.55)
5.8 (42.5)	6.9 (44.5)	2.96×10^{-2} (235)	4.8 (.69)	43.3 (110)	7.2 (45)	24.4 (76)	7.8 (46)	33.8×10^{-4} (7.2)	124 (.5)
6.4 (43.5)	8.3 (47)	3.01×10^{-2} (239)	3.9 (.57)	43.3 (110)	8.9 (48)	32.8 (91)	9.4 (49)	32.6×10^{-4} (6.95)	124 (.5)
6.7 (44)	8.6 (47.5)	2.99×10^{-2} (237)	3.9 (.56)	43.9 (111)	8.9 (48)	32.8 (91)	8.3 (47)	31.7×10^{-4} (6.75)	111 (.45)
5.3 (41.5)	6.4 (43.5)	3.01×10^{-2} (239)	4.1 (.6)	43.3 (110)	7.2 (45)	25.8 (78.5)	7.2 (45)	33.8×10^{-4} (7.2)	149 (.6)
6.1 (43)	7.2 (45)	3.01×10^{-2} (239)	3.8 (.59)	42.8 (109)	7.2 (45)	26.5 (79.5)	7.2 (45)	34.3×10^{-4} (7.3)	161 (.65)
6.1 (43)	7.2 (45)	3.01×10^{-2} (239)	4.1 (.6)	42.8 (109)	7.2 (45)	23.6 (74.5)	7.2 (45)	33.4×10^{-4} (7.1)	149 (.6)

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TABLE D-5 (Continued)
FIRST SUBLIMATOR
MISSION TEST (NON VENTING) RESULTS SUMMARY

LIQUID LOOP				GAS LOOP					
Tin °C (°F)	Tout °C (°F)	Flow Kg/sec (lb/hr)	ΔP Kpa (psi)	Tin °C (°F)	Tout °C (°F)	DPin °C (°F)	DPout °C (°F)	Flow m^3/sec (cfm)	ΔP Pa (in H_2O)
6.1 (43)	7.2 (45)	3.01×10^{-2} (239)	4.1 (6)	42.8 (109)	7.2 (45)	24.4 (76)	7.2 (45)	34.3×10^{-4} (7.3)	161 (.65)
6.1 (43)	7.5 (45)	3.01×10^{-2} (239)	4.1 (.59)	42.8 (109)	7.8 (46)	29.2 (84.5)	7.8 (46)	32.9×10^{-4} (7.0)	161 (.55)
6.4 (43.5)	8.1 (46.5)	2.96×10^{-2} (235)	4.0 (.58)	42.8 (109)	8.9 (48)	29.2 (84.5)	8.6 (47.5)	32.7×10^{-4} (6.95)	136 (.55)

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TABLE D-6

STEADY STATE TEST RESULTS SUMMARY

FIRST SUBLIMATOR

POROUS PLATE NUMBER 2

	LIQUID LOOP				GAS LOOP						
	Tin °C (°F)	Tout °C (°F)	Flow Kg/sec (lb/hr)	Delta P KPa (psi)	Tin °C (°F)	Tout °C (°F)	DPin °C (°F)	DPout °C (°F)	Flow m^3/sec (cfm)	Delta P Pa (in H_2O)	Total Heat Load Watts (Btu/Hr)
TEST RESULTS	1.4 (34.5)	.8 (33.5)	3.04×10^{-2} (242)	5.4 (.79)	21.1 (70)	2.5 (36.5)	10 (50)	3.3 (38)	2.8×10^{-3} (5.87)	87 (.35)	114 (390)
	1.7 (35)	1.1 (34)	3.00×10^{-2} (238)	5.3 (.78)	32.2 (90)	2.22 (36)	18.6 (65.5)	3.6 (38.5)	2.8×10^{-3} (6.05)	75 (.3)	170 (580)
	2.8 (37)	2.2 (36)	3.02×10^{-2} (240)	5.1 (.74)	42.8 (109)	2.8 (37)	33.1 (91.5)	3.6 (38.5)	3.1×10^{-3} (6.5)	100 (.4)	334 (1,140)
	5.8 (42.5)	3.1 (37.5)	3.10×10^{-2} (246)	4.8 (.7)	22.2 (72)	4.44 (40)	9.2 (48.5)	4.7 (40.5)	2.8×10^{-3} (5.89)	75 (.3)	393 (1,340)
	6.1 (43)	3.3 (38)	3.00×10^{-2} (238)	4.6 (.68)	33.6 (92.5)	4.2 (39.5)	18.6 (65.5)	5 (41)	2.8×10^{-3} (6.05)	75 (.3)	446 (1,520)
	7.2 (45)	4.4 (40)	3.03×10^{-2} (240)	4.6 (.66)	42.8 (109)	2.8 (40)	33.1 (91.5)	5.3 (41.5)	3.1×10^{-3} (6.6)	100 (.4)	616 (2,100)
	10.3 (52.5)	5.6 (42)	3.07×10^{-2} (244)	4.6 (.66)	22.8 (73)	6.7 (44)	9.4 (49)	5.6 (42)	2.8×10^{-3} (5.93)	70 (.28)	783 (2,670)
	11.4 (52.5)	5.8 (42.5)	3.02×10^{-2} (240)	4.4 (.62)	33.3 (92)	6 (43)	19.2 (66.5)	6.7 (44)	2.8×10^{-3} (6.05)	75 (.3)	798 (2,720)
	12.2 (54)	6.7 (44)	3.02×10^{-2} (240)	4.2 (.61)	43.9 (111)	6.7 (44)	31.9 (89.5)	7.5 (45.5)	3.1×10^{-3} (6.5)	112 (.45)	938 (3,200)
SPEC	12.22 (54) inlet	7.22 (45) max out	3.03×10^{-2} (240) nominal	5.0 (.728 psi) max at Tin = 12.22°C (54°F)	43.33 (110) inlet	10.00 (50) max outlet	32.78 (91) inlet	10.0 (50) max outlet	2.7×10^{-3} (5.7 cfm) nominal	697 (2.8) max at 43.33 (110°F) and DP = 32.8°C (91°F)	909 (3,100) Max Load

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TABLE D-7

MISSION TEST (VENTING) RESULTS SUMMARY

FIRST SUBLIMATOR

POROUS PLATE NUMBER 2

	LIQUID LOOP				GAS LOOP					
	T_{in} °C (°F)	T_{out} °C (°F)	Flow Kg/sec (lb/hr)	Delta P KPa (psi)	T_{in} °C (°F)	T_{out} °C (°F)	DP_{in} °C (°F)	DP_{out} °C (°F)	Flow m^3/sec (cfm)	Delta P Pa (in H_2O)
MISSION CYCLE NUMBER 1	7.2 (45)	3.9 (39)	3.02×10^{-2} (240)	4.5 (.65)	45 (113)	6.7 (44)	21.7 (71)	4.4 (40)	2.7×10^{-3} (5.65)	111 (.45)
	7.2 (45)	4.2 (39.5)	3.0×10^{-2} (238)	4.7 (.68)	46 (115)	5.6 (42)	24.2 (75.5)	3.3 (38)	3.0×10^{-3} (6.35)	123 (.5)
	6.9 (44.5)	4.2 (39.5)	3.1×10^{-2} (246)	4.3 (.63)	44.4 (112)	5.8 (42.5)	23.9 (75)	5.6 (42)	3.0×10^{-3} (6.44)	148 (.6)
	12.2 (54)	6.7 (4.4)	3.12×10^{-2} (248)	4.3 (.63)	45.6 (114)	7.2 (45)	28.6 (83.5)	7.2 (45)	3.1×10^{-3} (6.49)	136 (.55)
	10.6 (51)	6.1 (43)	3.12×10^{-2} (248)	4.5 (.66)	44.4 (112)	6.7 (44)	26.1 (79)	6.7 (44)	3.0×10^{-3} (6.40)	136 (.55)
	7.5 (45.4)	4.4 (40)	3.1×10^{-2} (246)	4.8 (.70)	44.4 (112)	5.6 (42)	24.4 (76)	5.3 (41.5)	2.9×10^{-3} (62.7)	136 (.55)

Time to start up - 20 Seconds

Time to shutdown - 2 Minutes

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TABLE D-8

MISSION TEST (VENTING) RESULTS SUMMARY

FIRST SUBLIMATOR

POROUS PLATE NUMBER 2

	LIQUID LOOP				GAS LOOP					
	T_{in} °C (°F)	T_{out} °C (°F)	Flow Kg/sec (lb/hr)	Delta P Kpa (psi)	T_{in} °C (°F)	T_{out} °C (°F)	DP_{in} °C (°F)	DP_{out} °C (°F)	Flow m^3/sec (cfm)	Delta P Pa (in H_2O)
MISSION CYCLE 2	2.5 (36.5)	1.9 (35.5)	3.0×10^{-2} (238)	5.0 (.73)	40.3 (104.5)	3.1 (37.5)	29.4 (85)	3.9 (39)	2.7×10^{-3} (5.63)	87 (.35)
	2.5 (36.5)	1.9 (35.5)	3.02×10^{-2} (240)	5.0 (.73)	41.1 (106)	3.1 (37.5)	29.4 (85)	3.9 (39)	2.8×10^{-3} (5.69)	87 (.35)
	6.4 (43.5)	3.6 (38.5)	3.05×10^{-2} (242)	4.66 (.68)	41.1 (106)	4.2 (39.5)	23.6 (74.5)	5.3 (41.5)	2.7×10^{-3} (5.74)	87 (.35)
	6.4 (43.5)	3.6 (38.5)	3.05×10^{-2} (242)	4.66 (.68)	41.9 (107.5)	4.4 (40)	23.6 (74.5)	5 (41)	3.0×10^{-3} (6.41)	87 (.35)
	12.8 (55)	7.2 (45)	3.07×10^{-2} (244)	4.2 (.61)	44.2 (111.5)	6.7 (44)	33.1 (91.5)	6.9 (44.5)	3.0×10^{-3} (6.44)	99 (.4)
	9.4 (49)	5 (41)	3.05×10^{-2} (242)	4.2 (.62)	42.5 (108.5)	5.6 (42)	24.4 (76)	5.8 (42.5)	3.1×10^{-3} (6.54)	99 (.4)
	9.4 (49)	5 (41)	3.0×10^{-2} (238)	4.2 (.62)	41.9 (107.5)	5.6 (42)	24.7 (76.5)	6.1 (43)	3.1×10^{-3} (6.52)	99 (.4)
	6.4 (43.5)	3.6 (38.5)	3.02×10^{-2} (240)	4.5 (.65)	42.2 (108)	4.4 (4.0)	23.9 (75)	4.7 (40.5)	2.9×10^{-3} (6.08)	99 (.4)
	2.5 (36.5)	1.9 (35.5)	3.02×10^{-2} (240)	4.8 (.70)	43.3 (110)	3.6 (38.5)	28.9 (84)	3.9 (39)	3.1×10^{-3} (6.55)	99 (.4)

Time to start up - 15 Seconds
Time to shutdown - 4.8 Minutes

HAMILTON STANDARD Division of UNITED TECHNOLOGIES

TABLE D-9

MISSION TEST (VENTING) RESULTS SUMMARY

FIRST SUBLIMATOR

POROUS PLATE NUMBER 2

	LIQUID LOOP				GAS LOOP					
	T_{in} °C (°F)	T_{out} °C (°F)	Flow Kg/sec (lb/hr)	Delta P KPa (psi)	T_{in} °C (°F)	T_{out} °C (°F)	DP_{in} °C (°F)	DP_{out} °C (°F)	Flow m^3/sec (cfm)	Delta P Pa (in H_2O)
MISSION CYCLE 3	3.1 (37.5)	2.2 (36)	3.02×10^{-2} (240)	4.8 (.70)	43.3 (110)	3.9 (39)	28.6 (83.5)	4.2 (39.5)	2.9×10^{-3} (6.18)	136 (.55)
	6.1 (43)	3.3 (38)	3.0×10^{-2} (238)	4.7 (.68)	42.2 (108)	4.4 (40)	23.1 (73.5)	5.3 (41.5)	3.0×10^{-3} (6.35)	136 (.55)
	6.4 (43.5)	3.6 (38.5)	3.02×10^{-2} (240)	4.7 (.68)	42.2 (108)	4.4 (40)	24.4 (76)	5.6 (42)	3.0×10^{-3} (6.39)	136 (.55)
	12.5 (54.5)	6.9 (44.5)	3.0×10^{-2} (238)	4.1 (.60)	42.8 (109)	6.4 (43.5)	32.2 (90)	7.2 (45)	3.2×10^{-3} (6.76)	149 (.6)
	8.9 (48)	47 (40.5)	3.02×10^{-2} (240)	4.2 (.62)	42.8 (109)	5.3 (41.5)	23.9 (75)	6.1 (43)	3.0×10^{-3} (6.4)	136 (.55)
	8.9 (48)	4.7 (40.5)	3.0×10^{-2} (238)	4.2 (.62)	42.8 (109)	5.3 (41.5)	23.9 (75)	6.1 (43)	3.0×10^{-3} (6.74)	136 (.55)

Time to start up - 20 Seconds
Time to shutdown - 4 Minutes

TABLE D-10

STEADY STATE TEST RESULTS SUMMARY

SECOND SUBLIMATOR

POROUS PLATE NUMBER 1

	LIQUID LOOP				GAS LOOP						Total
	Tin °C (°F)	Tout °C (°F)	Flow Kg/sec (lb/hr)	Delta P KPa (psi)	Tin °C (°F)	Tout °C (°F)	DP_{in} °C (°F)	DP_{out} °C (°F)	Flow m^3/sec (cfm)	Delta P Pa (in H_2O)	Head Load Watts (Btu/Hr)
TEST RESULTS	1.1 (34)	.6 (33)	3.02×10^{-2} (240)	3.4 (.54)	22.5 (72.5)	2.5 (36.5)	10.0 (50)	3.1 (37.5)	2.7×10^{-3} (5.7)	38 (.15)	117 (400)
	1.4 (34.5)	.9 (33.5)	3.02×10^{-2} (240)	3.8 (.56)	33.1 (91.5)	2.2 (36)	17.8 (64)	3.6 (38.5)	2.8×10^{-3} (5.95)	38 (.15)	167 (570)
	2.5 (36.5)	2.0 (35.5)	3.02×10^{-2} (240)	3.3 (.48)	43.3 (110)	3.3 (38)	32.2 (90)	3.6 (38.5)	3.4×10^{-3} (7.27)	63 (.25)	337 (1,150)
	4.7 (40.5)	2.2 (36)	3.02×10^{-2} (240)	2.9 (.42)	22.8 (73)	4.4 (40)	11.1 (52)	5.3 (41.5)	2.7×10^{-3} (5.7)	38 (.15)	370 (1,260)
	5.0 (41)	2.2 (36)	3.02×10^{-2} (240)	3.4 (.5)	32.5 (90.5)	4.4 (40)	18.9 (66)	6.1 (43)	2.9×10^{-3} (6.3)	38 (.15)	452 (1,540)
	7.8 (46)	5.0 (41)	3.02×10^{-2} (240)	2.7 (.4)	44.1 (111.5)	6.7 (44)	32 (89.5)	6.4 (43.5)	3.3×10^{-3} (7.08)	75 (.3)	636 (2,170)
	9.2 (48.5)	4.4 (40)	3.02×10^{-2} (240)	2.9 (.42)	23.1 (73.5)	7.5 (45.5)	12 (53.5)	11.7 (53)	2.8×10^{-3} (5.8)	38 (.15)	674 (2,300)
	10.3 (50.5)	4.7 (40.5)	3.02×10^{-2} (240)	2.7 (.4)	32.1 (91.5)	7.5 (45.5)	18.9 (66)	8.1 (46.5)	2.9×10^{-3} (6.3)	50 (.2)	815 (2,780)
	13.3 (56)	7.8 (46)	3.02×10^{-2} (240)	2.1 (.3)	45.5 (114)	9.7 (49.5)	33.3 (92)	10 (50)	3.5×10^{-3} (7.4)	75 (.3)	988 (3,370)
SPEC	12.22 (54) inlet	7.22 (45) max out	3.03×10^{-2} (240) nominal	5.0 (.728 psi) max at T_{in} = 12.22°C (54°F)	43.33 (110) inlet	10.00 (50) max outlet	32.78 (91) inlet	10.0 (50) max outlet	2.7×10^{-3} (5.7 cfm) nominal	697 (2.8) max at 43.33 (110°F) and DP = 32.8°C (91°F)	909 (3,100) Max Load

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TABLE D-11

STEADY STATE TEST (NON VENTING) RESULTS SUMMARY

SECOND SUBLIMATOR

POROUS PLATE NUMBER 1

LIQUID LOOP				GAS LOOP					
T_{in} °C (°F)	T_{out} °C (°F)	Flow Kg/sec (lb/hr)	Delta P KPa (psi)	T_{in} °C (°F)	T_{out} °C (°F)	DP_{in} °C (°F)	DP_{out} °C (°F)	Flow m^3/sec (cfm)	Delta P Pa (in H_2O)
7.2 (45)	8.9 (48)	3.02×10^{-2} (240)	2.3 (.33)	43.3 (110)	8.3 (47)	3.2 (90)	8.6 (47.5)	3.3×10^{-3} (6.93)	50 (.2)
6.7 (44)	7.5 (45.5)	3.02×10^{-2} (240)	2.3 (.33)	43 (109.5)	8.0 (46.5)	26.7 (80)	8.0 (46.5)	3.0×10^{-3} (6.45)	50 (.2)
7.0 (44.5)	7.8 (46)	3.02×10^{-2} (240)	2.3 (.33)	43 (109.5)	8.0 (46.5)	21.1 (70)	8.0 (46.5)	2.8×10^{-3} (6.0)	25 (.1)

TABLE D-12
THERMAL CONTROL SYSTEM
MISSION TEST (ROOM START)
DATA SUMMARY

Liquid Loop				Gas Loop						Total Heat Load Watts (Btu/Hr)
Flow Kg/Hr (Lb/Hr)	T_{in} °C (°F)	T_{out} °C (°F)	Subl T_{out} °C (°F)	Flow M^3/Sec (ACFM)	T_{in} °C (°F)	T_{out} °C (°F)	Subl T_{out} °C (°F)	T_{DPin} °C (°F)	T_{DPout} °C (°F)	
110 (241)	24.7 (76.5)	24.7 (76.5)	24.7 (76.5)	2.9×10^{-3} (6.25)	34.7 (94.5)	24.1 (75.5)	25 (77)	18.6 (65.5)	18.0 (64.5)	Pre Start Up
110 (241)	3.0 (37.5)	2.8 (37)	2.8 (37)	2.9×10^{-3} (6.25)	43.3 (110)	9.4 (49)	4.7 (40.5)	28.9 (84)	4.1 (39.5)	270 (920)
110 (243)	7.2 (45)	4.7 (40.5)	4.4 (40)	2.9×10^{-3} (6.3)	43.3 (110)	9.1 (48.5)	5.6 (42)	23.3 (74)	5.6 (42)	510 (1740)
110 (241)	6.4 (43.5)	4.1 (39.5)	3.9 (39)	2.9×10^{-3} (6.2)	42.2 (108)	8.3 (47)	5.0 (41)	12.2 (54)	5.0 (41)	432 (1475)
110 (241)	12.2 (54)	6.7 (44)	6.7 (44)	2.9×10^{-3} (6.25)	42.2 (108)	9.7 (49.5)	6.9 (44.5)	7.8 (46)	6.7 (44)	789 (2690)
110 (241)	9.7 (49.5)	5.6 (42)	5.6 (42)	2.9×10^{-3} (6.25)	42.2 (108)	9.1 (48.5)	6.4 (43.5)	9.7 (49.5)	5.6 (42)	623 (2125)
110 (241)	6.9 (44.5)	4.1 (39.5)	4.4 (40)	3.1×10^{-3} (6.65)	43 (109.5)	8.0 (46.5)	5.3 (41.5)	10.8 (51.5)	5.3 (41.5)	453 (1545)
110 (241)	6.9 (44.5)	4.1 (39.5)	4.4 (40)	2.9×10^{-3} (6.25)	43 (109.5)	8.0 (46.5)	5.3 (41.5)	10.8 (51.5)	5.3 (41.5)	462 (1540)

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TABLE D-13
THERMAL CONTROL SYSTEM
MISSION TEST (COLD START)
DATA SUMMARY

Liquid Loop				Gas Loop						
Flow Kg/Hr (Lb/Hr)	T_{in} °C (°F)	T_{out} °C (°F)	Subl T_{out} °C (°F)	Flow M^3/Sec (ACFM)	T_{in} °C (°F)	T_{out} °C (°F)	Subl T_{out} °C (°F)	T_{DPin} °C (°F)	T_{DPout} °C (°F)	Total Heat Load Watts (Btu/Hr)
110 (242)	1.7 (35)	2.2 (36)	2.2 (36)	3.2×10^{-3} (6.9)	27.8 (82)	12.8 (55)	7.2 (45)	9.4 (49)	5.6 (42)	Pre Start Up
110 (241)	3.9 (39)	3.3 (38)	3.6 (38.5)	3.3×10^{-3} (6.98)	42 (107.5)	10.3 (50.5)	6.7 (44)	28.6 (83.5)	5 (41)	396 (1350)
110 (242)	7.8 (46)	5.3 (41.5)	5.3 (41.5)	2.9×10^{-3} (6.3)	43.3 (100)	10.8 (51.5)	7.5 (45.5)	23.9 (75)	5.8 (42.5)	569 (1940)
109 (240)	7.8 (46)	5.3 (41.5)	5.3 (41.5)	2.9×10^{-3} (6.3)	44.5 (112.5)	10.3 (50.5)	7.5 (45.5)	23.9 (75)	5.8 (42.5)	587 (2000)
108 (238)	7.8 (46)	5.3 (41.5)	5.3 (41.5)	3.0×10^{-3} (6.4)	45 (113.5)	10.3 (50.5)	7.5 (45.5)	24.7 (76.6)	6.9 (44.5)	616 (2100)
110 (241)	14.1 (57.5)	8.6 (47.5)	8.3 (47)	3.3×10^{-3} (7.05)	45.6 (114)	11.4 (52.5)	9.4 (49)	32.2 (90)	8.3 (47)	1085 (3700)
109 (240)	10.6 (51)	6.7 (44)	6.4 (43.5)	3.0×10^{-3} (6.35)	44.4 (112)	11.1 (52)	8.9 (48)	23.2 (75.5)	6.9 (44.5)	798 (2720)
109 (240)	10.6 (51)	6.7 (44)	6.7 (44)	3.0×10^{-3} (6.44)	44.4 (112)	11.1 (52)	8.6 (47.5)	24.7 (76.5)	7.5 (45.5)	795 (2710)
109 (240)	4.1 (39.5)	3.6 (38.5)	3.6 (38.5)	3.2×10^{-3} (6.72)	44.4 (112)	9.4 (49)	6.7 (44)	29.4 (85)	6.1 (43)	431 (1470)
110 (241)	4.1 (39.5)	3.6 (38.5)	3.6 (38.5)	3.1×10^{-3} (6.52)	44.4 (112)	9.1 (48.5)	6.4 (43.5)	28.3 (83)	5.6 (42)	402 (1370)

TABLE D-14
THERMAL CONTROL SYSTEM
MISSION TEST (HOT START)
DATA SUMMARY

Liquid Loop				Gas Loop						
Flow Kg/Hr (Lb/Hr)	T_{in} °C (°F)	T_{out} °C (°F)	Subl T_{out} °C (°F)	Flow M^3/Sec (ACFM)	T_{in} °C (°F)	T_{out} °C (°F)	Subl T_{out} °C (°F)	T_{DPin} °C (°F)	T_{DPout} °C (°F)	Total Heat Load Watts (Btu/Hr)
109 (240)	41.6 (107)	41.6 (107)	41.9 (107.5)	3.2×10^{-3} (6.75)	45 (113)	38 (101)	42.2 (108)	28.9 (84)	27.5 (81.5)	Pre Start Up
109 (240)	4.4 (40)	3.9 (39)	3.9 (39)	3.2×10^{-3} (6.78)	(120)	(70)	(50.5)	(82.5)	(44.4)	487 (1,660)
112 (246)	8.9 (48)	6.4 (43.5)	5.9 (42.5)	3.0×10^{-3} (6.38)	40.6 (115)	15.6 (60)	9.4 (49)	23.6 (74.5)	6.9 (44.5)	765 (2,610)
109 (240)	13 (55.5)	8.3 (47)	8.3 (47)	3.4×10^{-3} (7.23)	46 (115)	15.6 (60)	9.7 (49.5)	32.8 (91)	8.6 (47.5)	1,093 (3,660)
108 (237)	9.7 (49.5)	6.1 (43)	6.1 (43)	3.0×10^{-3} (6.46)	45 (113)	13.6 (56.5)	8.9 (48)	24.1 (75.5)	8.3 (47)	792 (2,700)
108 (237)	7.5 (45.5)	5.3 (41.5)	5.3 (41.5)	3.0×10^{-3} (6.46)	45 (113)	13.0 (55.5)	8.0 (46.5)	24.1 (75.5)	7.2 (45)	651 (2,220)
106 (234)	3.9 (39)	3.6 (38.5)	3.6 (38.5)	3.1×10^{-3} (6.7)	44.4 (112)	11.7 (53)	6.4 (43.5)	28.9 (84)	5.6 (42)	457 (1,560)

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APPENDIX E

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BIBLIOGRAPHY

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